

# MAG External Truck Travel Model Development

## final report

*prepared for*

**Maricopa Association of Governments**

*prepared by*

**Cambridge Systematics, Inc.**



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# 1.0 Introduction

The Maricopa Association of Governments (MAG) is a Council of Governments that serves as the regional transportation planning agency for the metropolitan Phoenix area. MAG, through a contract with Cambridge Systematics, Inc. (CS), recently updated the Internal Truck Travel Model to a base year of 2006 that estimates Medium and Heavy internal truck trips at the zonal level traveling within the MAG modeling area. That is, both the origins and destinations of these internal truck trips are within the MAG region. The external truck trips, which have at least one or both ends outside the region, were not updated in that study due to the lack of sufficient data and resources.

MAG recently acquired a commodity flow database from Arizona State Department of Transportation (AZDOT) that represents commodity flows coming into, leaving and going through the State of Arizona. This database is called TRANSEARCH that was purchased by AZDOT from IHS Global Insight, Inc. MAG also recently completed a comprehensive external station cordon survey of all vehicle types. The survey data included vehicle classification counts at eight of the 11 external stations along the periphery of the MAG modeling area. The classification count data was categorized into FHWA classification scheme, which is consistent with what the MAG truck model produces at the link level.

MAG's regional travel forecasting model is the main tool for forecasting future traffic volumes and to feed into air quality models to determine emissions by vehicle type for forecast years. As trucks contribute a significant portion of air quality emissions, it is extremely important to update and validate the truck model, both internal and external. With the availability of the recently acquired TRANSEARCH database and new external cordon surveys, MAG awarded a task order to CS, through the ongoing modeling on-call contract, to update and validate the external truck travel model.

The scope of work for this task order included a description of the data needs for updating MAG's external truck trip tables, a procedure to develop the external truck model, a validation plan, procedure to develop external truck trip forecasts, and preparation of this final report.

This report provides the model development process and data requirements, review and processing of the TRANSEARCH database, external truck model estimation, calibration and validation of the whole base year truck model (internal and external combined), model results, findings and recommendations, and forecast year data preparation and model results.



## 2.0 Model Development Process

This chapter provides a review of the existing external truck travel model, recommendations for improvements to the modeling procedure, and data that is required to accomplish the improvements.

### 2.1 REVIEW OF PREVIOUS EXTERNAL TRUCK MODEL

The external truck model was first developed back in the early 1990s based on an external vehicle trip survey. This was then updated in 1998 based on another external vehicle survey, where EE truck travel was estimated separately from the EI/IE truck travel. The EE truck travel was determined using the external vehicle survey data to create a base year trip table for 1998. One growth rate was used to estimate future external travel for all the external stations.

The EI/IE model was developed to predict the destination of trips entering the region at each external station based on household and employment data for those zones. Travel times between the external stations and the internal zones were used to distribute truck trips. This process assumed a trip between the external station and an internal zone would be inversely related to travel time assuming all other factors are equal. As the distance increases, the likelihood of a trip between the zone and the external station decreases. For truck trips that had destinations outside the region, the EI truck trips were interchanged or transposed to obtain the IE truck trip tables. This was done assuming that all trucks entering the region would have to leave the region as well. For forecasting EI/IE truck travel, growth factors based on population growth from the base year 1998 to the target forecast year were used.

This external truck model was not updated as part of the recent internal truck model update which considered only those trucks that has both the trip ends inside the MAG region.

Table 2.1 shows a summary of the existing external truck model that has not been updated since 1998. Also, the external truck trips have been allocated equally among external-internal (EI) and internal-external (IE) movements.

**Table 2.1 Existing External Truck Model Summary**

Truck Type	External-Internal	Internal-External	External-External
Light Trucks	56,405	56,405	There were no specific E-E truck trips; All vehicle trips were combined.
Medium Trucks	1,965	1,965	
Heavy Trucks	11,311	11,311	
<b>Total Trucks</b>	<b>69,681</b>	<b>69,681</b>	<b>15,448</b>

## 2.2 OVERVIEW OF IMPLEMENTED IMPROVEMENTS TO THE MAG EXTERNAL TRUCK MODEL

State-of-the-practice metropolitan truck models are hybrids that blend commodity flow modeling techniques with land use-based truck modeling techniques. Commodity flow databases such as TRANSEARCH tend to be relatively accurate for intercounty flows, but undercount intracounty flows because commodity flow databases rely in part on economic input-output data that ultimately are based on financial transactions between producers and consumers of goods. Also, in an urban area many truck moves are not easily traced to such transactions. Moves from warehouses and distribution centers, repositioning of fleets, drayage moves, parcel delivery, and the like are generally short-distance trips in which there may not be an economic exchange of the goods from one party to another. To compensate for the lack of inclusion of the shorter distance trips in commodity flow data, and to account for types of trucks that do not carry freight, local truck trips are usually generated based on local employment and economic factors using trip generation rates. This is precisely being done with MAG's internal truck modeling process where truck trips are generated at the zone level and distributed to various origins and destinations using land use-to-land use gravity models.

Several terms are used to refer to these two trip types, including commodity flow trips versus locally generated trips, external versus internal truck trips, and long-haul versus local truck trips. Taking advantage of the relative strength of the commodity long-haul approach and the truck short-haul approach within the same truck travel model is referred to as a "hybrid approach". The availability of TRANSEARCH commodity flow database to MAG prompted the development and application of this hybrid approach to MAG's truck model. The modeling framework based on commodity flows is described in the following section, which forms the basis for the external truck model development.

### *Approach*

The 2005 TRANSEARCH data is the primary source of commodity flow data that was used to develop the new External Truck Model. This database consists of commodity flows in tonnages at the county level, which includes outbound flows (leaving MAG region), inbound flows (entering MAG region), and through flows (passing through MAG region). The basic approach that will be followed is to determine relationships among these freight flows and the corresponding industries that produce these flows. The TRANSEARCH data has zip code-level data, which was used along with MAG's employment data to develop these relationships. Some tonnage is expected to move to transload locations, which are not directly related to the producing or consuming industries for that commodity. Such locations are typically rail terminals, ports, airports, and truck terminals, which are classified as special generators in this model. These

locations also serve as important freight tonnage originations or terminations of truck trips.

The following are key steps that were undertaken while disaggregating the commodity flow database by commodity type to create the internal trip ends at MAG TAZs based on 2007 2-digit North American Industrial Classification System (NAICS) employment distributions:

1. **QA/QC of TRANSEARCH Data** – The 2005 TRANSEARCH database was reviewed thoroughly and some of the key statistics were compared against other data sources to do a quality control. This step involved comparing the external freight flows that pass through the MAG region against the Freight Analysis Framework (FAF<sup>2</sup>) database, and comparing commodity distributions against other urban MPO regions. This task also involved processing the database and extracting flows for the MAG region from the statewide flow database. Additional details on how the processing was done are described in Chapter 3.
2. **Entry/Exit Points of Truck Flows** – The entry and exit points for truck flows in the TRANSEARCH database are determined by Global Insight by using certain routing routines or pre-determined paths and saved in the database. These entry and exit points were identified along the periphery of the Arizona statewide boundary. This, however, is not very useful, because the MAG External Model development will need entry and exit points of truck flows at the MAG regional boundary. Also, the available TRANSEARCH highway networks have centroid connectors in the middle of the County, which are more suitable for statewide analyses. The determination of entry and exit points specific to the MAG region was undertaken in consultation with MAG.
3. **Converting Annual to Daily Trucks** – As the 2005 TRANSEARCH is an annual database, the annual truck trips by commodity type at the 2-digit Standard Transportation Commodity Classification (STCC) level was converted over to daily truck trips by commodity type to the zip code level. Different factors have been used in different studies that vary from 260 to 310, and we chose the use of 300 days of truck operations to do the conversion.
4. **External Truck Trip Generation Model** – A bridge between STCC and NAICS was used, and the employment data was correlated to different commodity types to begin the regression model estimations by commodity type. The commodity types serve as the trip purpose for the External Truck Travel Model. This step serves as the trip generation component, and is necessary to develop relationships between employment and commodity type. This is based on the rationale that external truck trip generation for each commodity type is influenced by the underlying employment data. Due to the similarities between various commodity groups, the 2-digit STCC commodities were aggregated from 43 categories up to a handful of major

commodity groups (CG). The regression models by commodity type were not estimated separately for productions (IE) and attractions (EI). Based on judgment and past experience, various employment types were used as explanatory variables in the regression models for each of the major commodity groups. The models were then chosen based on model fit and t-stats of individual employment variables. These are described in more detail in Chapter 4.

5. **Growing 2005 to 2007 Commodity Flows** – The new base year model is for 2007; for this reason, growth factors were applied to the 2005 TRANSEARCH data to derive 2007 commodity flow data. The growth factors were based on employment growth between 2005 and 2007.
6. **External Truck Distribution Model** – The truck trip generation model generated productions and attractions at the TAZ level by commodity group. These were allocated or distributed to various origins and destinations, internal to the MAG region, using a gravity model. The congested time skims were used as impedances in the gravity model. The external-to-external (EE) truck trips were estimated directly from the TRANSEARCH database and added to the EI and IE truck trip tables. Growth factors from TRANSEARCH were used to derive the EE flows for future years.
7. **Integration of External Truck Model with MAG's Travel Model** – The new external truck trip tables derived from the above step were then added to the internal truck model trip tables. The Combined Truck Model was then integrated with MAG's Travel Demand Model, and multiclass assignments were performed along with auto trips.

The procedure described above was implemented in TransCAD and involved developing scripts in GISDK that was easy to implement and user-friendly. The developed product allows for easy conversion to new TAZ systems in the future and updates of any of the external model databases. This procedure also allows the user to input the necessary commodity flow and employment databases with any input TAZ structure that the user has available.

## 2.3 OVERVIEW OF INPUT MODEL DATA

The data required to update the External Truck Travel Model that can estimate internal-external (IE), external-internal (EI), and external-external (EE) through truck trip tables is described below. These data were reviewed, its validity was assessed, and any new data essential was prepared in the development of the External Truck Travel Model.

### *Employment Data*

The Internal Truck Model includes the employment data at the 2-digit NAICS level that is being used as a key input for the Internal Truck Travel Model. The use of this data is critical for the development of the internal trip end of the

external truck trip tables as the commodities from commodity flow databases can be easily correlated to industry sectors at the 2-digit NAICS level. Adequate guidance was provided to MAG staff in projecting the employment data by 2-digit NAICS level to each year from 2007 to 2030.

### *Classification Counts*

Vehicle classification counts are required to validate the External Travel Model. Observed data at every external station is essential for calibrating the number of truck trips coming in, going out of, and passing through the MAG region. In addition to this, truck classification counts inside the MAG region are also necessary to validate the whole truck model that includes both internal and external truck models. The following data sources were explored for calibrating and validating the External Truck Model and the whole truck demand model:

- External travel surveys;
- Classification counts on arterials; and
- Arizona Department of Transportation's (AZDOT) Freeway Management System (FMS) count data on freeways.

The different time periods and truck classifications schemes from the abovementioned data sources was taken in to considerations, and the data attributes were made consistent for use in this task. The base year of the Internal and External Truck Models was 2007. The previously developed Internal Truck Model was adjusted to reflect new base year (2007), so that the timing of the data collection remains consistent with base year estimations.

### *TRANSEARCH Data*

The acquired TRANSEARCH data is a commodity flow database developed by IHS Global Insight, Inc., that has information at the county level about the freight flows (in annual tonnages) in the State of Arizona. For this model development effort, freight flows that begin, end, and pass through the MAG region are analyzed. This data represents the 2005 freight flows in the region. The TRANSEARCH database also includes zip code-level information that was also used. The base year of MAG's Internal Truck Travel Model was changed to 2007, so 2005 TRANSEARCH data with minor adjustments are used for the 2007 External Truck Model development.

The 2005 TRANSEARCH database includes information on truck loads in addition to commodity flows. The TRANSEARCH data that is available at MAG has certain limitations as far as the Regional Truck Model development is concerned. The entry and exit points of the commodity and truck flows are included along the state boundary, which was transformed to the MAG region boundary. This required certain assumptions to be made while processing the database.

### *Existing External Truck Trips*

The existing external truck trip tables were reviewed and analyzed. Relevant information, such as truck splits between medium and heavy trucks, were incorporated into the new External Truck Model. These trip tables also served as a starting point for the model update work, and were considerably augmented with the use of TRANSEARCH database.

### *FAF<sup>2</sup> Database*

The Federal Highway Administration's (FHWA) FAF<sup>2</sup> database, which provides commodity flow data at an aggregate level (higher than county level), was used only as a check for reasonableness of the freight flows through the MAG region.

### *Model Skims, Networks, and Scripts*

The existing skimming process and skim data were used in the development of the external truck model. The underlying highway networks were obtained from MAG's latest travel demand model. In addition to this, model files in TransCAD GISDK scripts were also reviewed, and appropriate changes were made to integrate the newly updated truck demand model.

## 3.0 Review of TRANSEARCH Database

This chapter provides detailed description of the processing of TRANSEARCH database, aggregating commodity types into a major commodity groups, and developing an estimation database for use in developing parameters for the external truck model.

### 3.1 PROCESSING OF TRANSEARCH DATABASE

A series of steps were undertaken to process the 2005 TRANSEARCH commodity flow data. These are listed below.

1. A database with required fields was developed from the 2005 statewide TRANSEARCH data file, and was windowed to truck trips to, from, and through the MAG region (primarily Maricopa and Pinal Counties). The TRANSEARCH data file has zip codes within counties, but the routing information that was used to window the data was for entire counties. Any zip code origins or destinations resulting from this process, which are inside Maricopa or Pinal Counties, but outside the MAG model boundary and do not connect to the MAG region, were discarded. That is, flows that begin and end outside of the MAG model boundary are excluded from the model development process.
2. An allocation of all TRANSEARCH origins and destinations outside of Maricopa and Pinal County, but those that contribute to freight flows related to MAG region, was done to the closest MAG External Station based on TRANSEARCH's routing data. The TRANSEARCH zip code origins and destinations were retained for Maricopa and Pinal Counties, and aggregated all records to STCC2.
3. The 2005 TRANSEARCH annual truck flows for all STCC2 commodities were converted to daily truck flows divided by 300 days per year. These flows were compared against that of FAF<sup>2</sup> at each MAG external station that has information on truck Annual Average Data Traffic (AADT). The results were generally consistent between TRANSEARCH and FAF<sup>2</sup>, and TRANSEARCH showed no truck flows through four low volume MAG external stations (namely, U.S. 60 in western part of Maricopa County: 823 trucks per day; SR 88 at Maricopa/Pinal county line: 823 trucks per day; SR 79 in southern part of Pinal County: 271 trucks per day; and SR 85 in southern part of Maricopa County: 217 trucks per day). Based on this finding, the TRANSEARCH flow table was used as a seed for an Iterative Proportional Fitting or Fratar adjustment technique using average weekday

truck directional volumes for all MAG external stations. These volumes were provided by MAG from the recently completed external station surveys.

4. Reviewed the list of STCC2 commodities in the TRANSEARCH data and the list of NAICS2 employment types to develop a smaller group of major commodity groups for use in the External Truck Model. A description of these commodity groups is presented in the next section.
5. Reviewed the TAZ and zip code-level NAICS2 employment data provided by MAG. It was found that zip code shape files used for establishing the TAZ correspondence file were not consistent with those used by IHS Global Insight in developing the 2005 AZDOT TRANSEARCH data file. MAG requested IHS Global Insight to provide the shape file of zip codes that was used in developing the TRANSEARCH. This was used to build a cross-walk between TAZ to TRANSEARCH's units of geography, and aggregated MAG's NAICS2 TAZ employment to TRANSEARCH's geography.
6. For EE trips, growth factors were derived from a ratio of 2005 units and 2030 forecast units (annual trucks) from the TRANSEARCH data files. For the four external stations, which have no data from TRANSEARCH, average growth factors were developed, so that truck flows are generated at these four stations as well in the future.
7. In order to use TRANSEARCH for developing friction factors for the gravity model, average trip lengths were computed between external stations and centroids representative of TRANSEARCH's geographical units or zip code tabulation areas (ZCTA). The shape file of TRANSEARCH's ZCTAs was used to identify centroids. The data obtained from MAG travel model was a skim table that included all external stations, zip code origins and zip code destinations. These friction factors were ultimately reconciled to MAG TAZs.

## 3.2 TRANSEARCH COMMODITY GROUPINGS

The 2005 AZ TRANSEARCH database, from which MAG-specific information was extracted, contains 32 distinct STCC2 commodity codes, which are numerous enough to create data management problems. For example, a large number of trip tables will result; and additionally will require detailed distinctions among NAICS2 employment data, which is going to be used in developing the regression equations. In order to develop an aggregation scheme, the TRANSEARCH data was used to determine the most consistent groupings of those commodities with the observed commodity data.

The AZ TRANSEARCH actually lists commodity shipments at the STCC4 level. The STCC is a hierarchical classification system, such that more digits provide more detail, but the additional detail nests back to a smaller number of STCC digits. For example, STCC 2071 Candy and STCC 2034 Dried Fruit, as well as other STCC 20XX commodities, can all be aggregated to STCC 20 Processed Food Products. The STCC was developed by the Association of American Railroads to

exactly match the Standard Industrial Classification (SIC), the industrial classification in use at that time. The STCC code for a product corresponds directly to the SIC of the industry producing that product. While the NAICS has replaced the SIC system, a correspondence table between NAICS and SIC can provide the ability to assign a NAICS2 code to each TRANSEARCH record based on its STCC4 commodity code. A correspondence table between SIC4 and NAICS6 is available from the Bureau of Transportation Statistics web site. Since NAICS is also a hierarchical system, the NAICS6 codes can readily be equated to NAICS2 codes.

In order to develop groupings of STCC2 commodities, which are appropriate for Arizona, the SIC4/STCC4 to NAICS2 correspondence was used to assign a NAICS2 to each record. The shipments by truck were then aggregated by the NAICS2 and STCC2 of each record. In this manner, similarities between STCC2 commodities and their corresponding NAICS2 industry were determined. This summary is shown in Table 3.1.

**Table 3.1 Assignment of STCC2 to Commodity Groups (CG)**

STCC	STCC Name	NAICS2	NAICS2 Name	Annual Truck Units	CG #	% by NAICS	Commodity Group Name
01	Agriculture	11	Agriculture, Forestry, Fishing and Hunting	1,352,547	1	100%	Farm
08	Forestry	11	Agriculture, Forestry, Fishing and Hunting	3	1	100%	Farm
09	Fish	11	Agriculture, Forestry, Fishing and Hunting	242	1	100%	Farm
10	Metallic Ores	21	Mining	82	2	100%	Mining
13	Crude Petroleum	21	Mining	11	2	100%	Mining
14	Nonmetallic Minerals	21	Mining	447	2	100%	Mining
19	Ordinance	21	Mining	52	2	100	Mining
20	Food	31	Manufacturing, Consumer Nondurable	4,578,927	3	96%	Consumer
		11	Agriculture, Forestry, Fishing and Hunting	179,876		4%	
21	Tobacco	31	Manufacturing, Consumer Nondurable	4,408	3	100%	Consumer
22	Textiles	31	Manufacturing, Consumer Nondurable	117,553	3	100%	Consumer
23	Apparel	31	Manufacturing, Consumer Nondurable	702,167	3	90%	Consumer
		33	Manufacturing, Durable	76,123		10%	
		32	Manufacturing, Non-consumer Non-durable	5,953		1%	

STCC	STCC Name	NAICS2	NAICS2 Name	Annual Truck Units	CG #	% by NAICS	Commodity Group Name
24	Lumber	32	Manufacturing, Non-consumer Non-durable	381,407	4	47%	Lumber
		33	Manufacturing, Durable	237,458		29%	
		11	Agriculture, Forestry, Fishing and Hunting	191,319		24%	
25	Furniture	33	Manufacturing, Durable	517,824	6	100%	Durable
26	Paper	32	Manufacturing, Non-consumer Non-durable	375,783	5	100%	Nondurable
27	Printed Goods	51	Information	660,805	7	94%	Printing
		32	Manufacturing, Non-consumer Non-durable	40,162		6%	
28	Chemicals	32	Manufacturing, Non-consumer Non-durable	2,118,176	5	89%	Nondurable
		31	Manufacturing, Consumer Nondurable	145,632		6%	
		21	Mining	63,212		3%	
		33	Manufacturing, Durable	63,212		3%	
29	Petroleum	32	Manufacturing, Non-consumer Non-durable	818,234	5	100%	Nondurable
30	Rubber/Plastics	32	Manufacturing, Non-consumer Non-durable	121,625	5	91%	Nondurable
		31	Manufacturing, Consumer Nondurable	12,378		9%	
31	Leather	31	Manufacturing, Consumer Nondurable	33,445	3	67%	Consumer
		32	Manufacturing, Non-consumer Non-durable	8,129		16%	
		33	Manufacturing, Durable	8,129		16%	
32	Clay, Concrete, Glass	32	Manufacturing, Non-consumer Non-durable	2,504,992	5	73%	Nondurable
		21	Mining	869,405		25%	
		33	Manufacturing, Durable	36,466		1%	
33	Metal	33	Manufacturing, Durable	1,348,548	6	81%	Durable
		32	Manufacturing, Non-consumer Non-durable	324,280		19%	
34	Metal Products	33	Manufacturing, Durable	2,297,075	6	100%	Durable
35	Machinery	33	Manufacturing, Durable	1,813,420	6	98%	Durable
		31	Manufacturing, Consumer Nondurable	43,525		2%	
36	Electrical Equipment	33	Manufacturing, Durable	802,571	6	99%	Durable
		51	Information	6,392		1%	

STCC	STCC Name	NAICS2	NAICS2 Name	Annual Truck Units	CG #	% by NAICS	Commodity Group Name
37	Transportation Equipment	33	Manufacturing, Durable	2,959,684	6	98%	Durable
		81	Other Services (except Public Administration)	53,780		2%	
		54	Professional, Scientific, and Technical Services	19,628		1%	
38	Instruments	33	Manufacturing, Durable	208,359	6	84%	Durable
		32	Manufacturing, Non-consumer Non-durable	39,515		16%	
39	Misc. Mfg Products	33	Manufacturing, Durable	158,007	6	91%	Durable
		32	Manufacturing, Non-consumer Non-durable	15,837		9%	
		31	Manufacturing, Consumer Nondurable	487		0%	
40	Waste	48	TCU	1	8	100%	Misc. Freight
41	Misc. Freight Shipments	48	TCU	5	8	100%	Misc. Freight
42	Shipping Containers	49	Warehousing	7,324,792	9	100%	Empty trucks
50	Secondary & Warehouse	#N/A	#N/A	408,111	10	100%	Warehousing

For many STCC2 Commodities, the assignment of NAICS2 is exact, and the grouping of those STCC2 into a commodity group supported by that NAICS is clear. For example, STCC\_10-Metallic Ores, STCC\_13-Crude Petroleum, STCC\_14-Nonmetallic Minerals, and STCC\_19-Ordnance all are associated with NAICS 21-Mining. Since there is only a single NAICS2 employment category supporting all of these STCC2s, there is no reason to maintain separate commodities and a single Commodity Group, Mining, is proposed for all three of these STCC2 commodities. In a similar fashion, STCC\_01-Agriculture, STCC\_08-Forestry, and STCC\_09-Fish are all associated with NAICS 11-Agriculture, and so a single Commodity Group, Farm Products, is proposed. Additionally, STCC\_40-Waste and STCC\_41-Misc Freight Shipments are both associated with NAICS 48-Transportation, and a single Commodity Group, Miscellaneous Freight, is proposed. STCC\_50-Secondary is not an official STCC code, but is a code used by TRANSEARCH to indicate secondary shipments of goods from intermodal terminals and other distribution centers. So this is not associated with any NAICS2 industry, but is proposed as a single commodity group, Warehousing.

There are, however, exceptions where it is not that straight forward as explained above. For example, the Nondurable Manufactured goods, STCC20-29 and the Nondurable Manufactured Goods STCC30-39 are now supported by three NAICS codes. Additionally, while the commodities are uniquely linked at the

STCC4 and NAICS6 levels, those linkages do not aggregate hierarchically in the same fashion. For that reason, the magnitude of the NAICS2 assignments within each STCC2 was examined.

There is typically a dominant NAICS2 industry associated with each of these STCC2 manufacturing commodities as described below.

- NAICS 31, Consumer Manufacturing, is the dominant industry for STCC\_20-Food (96 percent), STCC\_21-Tobacco (100 percent), STCC\_22-Textiles (100 percent), STCC\_23-Apparel (90 percent), and STCC31-Leather (67 percent); and it is proposed that these all be grouped into a single Commodity Group, Consumer.
- NAICS 32, Nondurable Manufacturing, is the dominant industry for STCC\_26-Paper (100 percent); STCC\_28-Chemicals (89 percent); STCC\_29-Petroleum Products (100 percent); STCC\_30-Rubber and Plastics (91 percent); and STCC32-Clay, Concrete, and Glass (73 percent). It is proposed that these all be grouped into a single Commodity Group, Nondurable.
- NAICS 33, Durable Manufacturing, is the dominant industry for STCC\_25-Furniture (100 percent), STCC\_33-Metals (81 percent), STCC\_34-Metal Products (100 percent), STCC\_35-Machinery (98 percent), STCC\_36-Electrical Equipment (99 percent), STCC\_37-Transportation Equipment (98 percent), STCC\_38-Instruments (84 percent), and STCC39-Miscellaneous Manufactured Products (91 percent); and it is proposed that these all be grouped into a single Commodity Group, Durable.
- For STCC\_24-Lumber, while NAICS32 is the largest association by number of trucks (47 percent), it is not the majority. There are significant associations with NAICS33, Durable Manufacturing (29 percent) and NAICS11, Forestry (24 percent). For that reason, it is proposed that it be its own Commodity Group, Lumber.
- For STCC\_27-Printing, the association under NAICS is not with the manufacturing industries, NAICS31-33, but with NAICS 51, Information (e.g., STCC\_511110-Newspaper Publishers). For that reason, it is proposed that it be its own Commodity Group, Printing.

The 10 Commodity Groups that were proposed and finalized are shown in Table 3.2.

**Table 3.2 Proposed Commodity Groups (CG)**

CG Number	Name	STCC2s Included
1	Farm	STCC 01, 08, 09
2	Mining	STCC 10, 13, 14, 19
3	All Consumer Manufacturing	STCC 20, 21, 22, 23, 31
4	Lumber	STCC 24
5	(Non-Consumer) Nondurable Manufacturing	STCC 26, 28, 29, 30, 32
6	(Non-Consumer) Durable Manufacturing	STCC 25, 33, 34, 35, 36, 37, 38, 39
7	Printing	STCC 27
8	Miscellaneous Freight	STCC 40, 41
9	Empty trucks	STCC 42
10	Warehousing	STCC 50

### 3.3 DEVELOPMENT OF TRANSEARCH ESTIMATION DATABASE

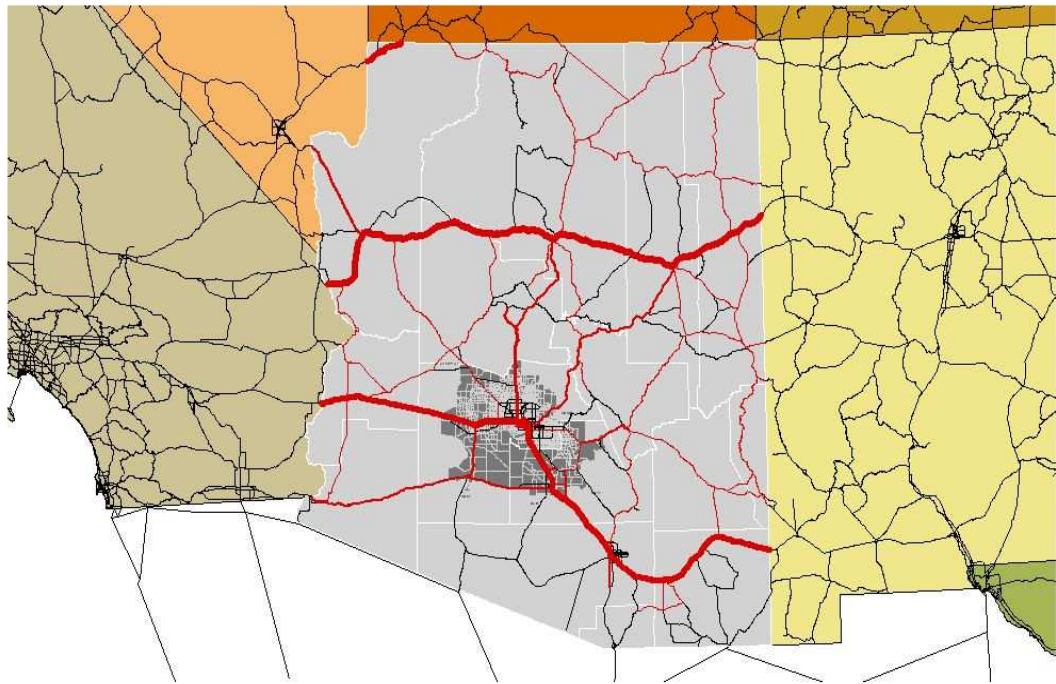
For use in the development of parameters for the External Truck Model, an estimation database was prepared using the TRANSEARCH database. This is one of the most comprehensive databases of detailed annual freight movements that includes “unlinked” database of trips, consisting of many multimodal “linked” trips between an origin and a destination involving truck and rail modes. The “linked” multimodal trips are reported in TRANSEARCH as two separate “unlinked” trips – the terminal where the intermodal exchange occurs is reported as an origin or a destination for each of the respective modes. The 2005 AZ TRANSEARCH contains over 2.5 million records with the following characteristics:

- All freight flows passing to, from, or through Arizona are defined by routing tables provided with TRANSEARCH.
- 759 distinct commodity codes at the STCC4 digit level.
- 270 distinct Origins and Destinations consisting of the 15 counties in Arizona, and U.S. BEA Economic Analysis area, Canadian Metropolitan areas and provinces, and Mexican states.
- 256 Zip Code Tabulation Areas (ZCTA) are reported for each of the 15 counties in Arizona. However, routings for truck and rail are only reported at the Arizona county level.

- 11 modes of transportation to move commodities are included in the database:
  - 4 submodes for trucks (Private, Truckload (TL), Less than TL (LTL) and Truck NEC (Not Elsewhere Classified));
  - 3 sub modes for rail (Rail Carload, Rail Intermodal and Rail NEC);
  - Air;
  - Water;
  - Pipeline; and
  - Other.
- Flows reported in annual tons, annual trucks, and annual value for 2005 and forecast for 2010, 2020, and 2030.

The TRANSEARCH flows using their routing tables are assigned to a highway network, as shown in Figure 3.1.

**Figure 3.1 AZ TRANSEARCH Truck Flows (2005)**



For use in the MAG External Truck Model, only a single truck mode was needed (the model cannot use the information about shipment size/operator type). The database was processed to aggregate truck records to a single mode, and to exclude records that involved other modes (as mentioned earlier TRANSEARCH

is an unlinked database. Any connection to other modes as part of a multimodal trip chain is not reported in TRANSEARCH).

The 4-digit STCC (e.g., STCC\_2010-Meat or Poultry, Fresh or Chilled; STCC\_2012-Meat, Fresh frozen, etc.) is more detailed than could be supported by 2-digit NAICS employment codes available to support the MAG External Model. The database was processed to aggregate commodities to 2-digit STCC code (e.g., STCC\_20-Processed Food Products).

The resulting table of Arizona truck flows by STCC2 was further processed to select only those records, which would pass through the MAG region. A shape file of the MAG model boundary was overlaid on a shape file of the TRANSEARCH truck network. By joining these files, a table was prepared of those TRANSEARCH highway segments within the MAG model region.

The TRANSEARCH Highway Routing Table consists of a route identifier and a highway segment number. Two fields, First Segment and Last Segment, are used together. For each route (path), First Segment is the first segment in Arizona and Last Segment is the last segment within Arizona for each route. That First Segment or Last Segment may be at the Arizona border for trips, which have one or both trips ends in BEAs outside of Arizona, or may be a highway segment within a county for trips which have one or both trip ends in an Arizona County.

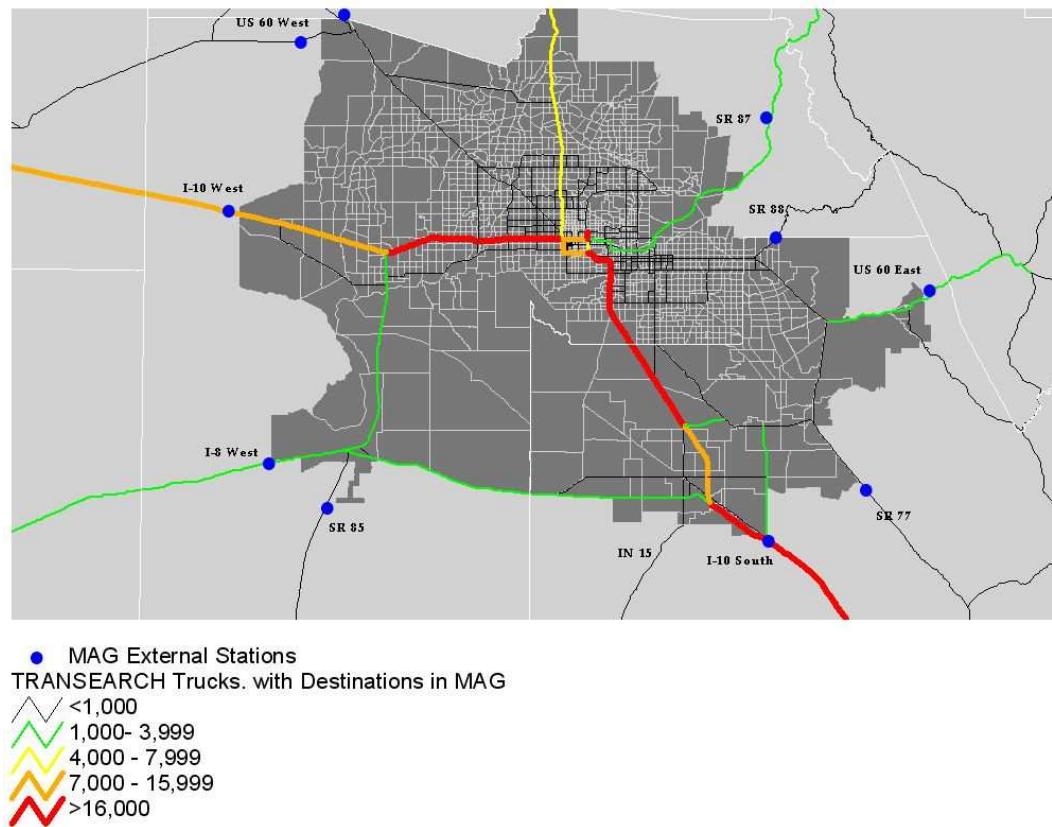
In the routing table, records with the same First Segment and Last Segment define the highway segments (links), which make up the route (path) between the First Segment and the Last Segment. The filter of highway segments which exist within the MAG model region was applied to the TRANSEARCH Highway Routing Table, in order to select only the routes which pass through the MAG model region. From the entire Arizona database of trucks by STCC2, the routing identifier for each record was used to select only those records, which have routes that pass through the MAG model region.

The TRANSEARCH truck flow database at this point consisted of only those truck flows, which pass through the MAG model region. While the TRANSEARCH origin identifier included the U.S. Census Zip Code Tabulation Area (ZCTA) for each record in Maricopa and Pinal Counties, it also included the ZCTA for the other 13 counties in Arizona and the BEAs for locations outside of Arizona. For use in the development of the MAG external model, it was necessary to replace the origin and/or destination outside of Maricopa and Pinal Counties with the station number through which the route in the Highway Routing Table would pass to reach that origin or destination.

The TRANSEARCH highway network crosses the MAG model boundary at 12 locations. One of these locations is Indian Route 15, an external station which is not included in the MAG model. Therefore, only 11 external stations where the TRANSEARCH network crosses the MAG boundary are identified, as shown in Figure 3.2. Those segments were associated with the origins and/or destinations outside of Maricopa and Pinal Counties and that association, as shown in Table 3.3, was used to add an additional origin or destination field

corresponding to the MAG model. Those “model” origins or destinations were the five-digit ZCTA code for trip ends in Maricopa County or Pinal County and the external stations (identified by TRANSEARCH Highway Segment Number) for trip ends outside of Maricopa and Pinal Counties. The database was reduced further by aggregating trip ends for records outside of Maricopa and Pinal Counties, identified by BEAs and other Arizona counties, to the External Station through which they pass.

**Figure 3.2 MAG External Stations and TRANSEARCH Networks**



The resulting MAG TRANSEARCH database of 46,393 records, which will be used to develop the MAG external model, includes the following:

- All freight flows passing to, from, or through the MAG model region, as defined by routing tables provided with TRANSEARCH;
- 33 distinct commodity codes at the STCC 2 digit level;
- 11 External Stations on the MAG model boundary;
- 129 ZCTA within Maricopa and Pinal Counties;
- One truck mode; and

- Flows reported in annual tons, annual trucks, and annual value for 2005 and forecast for 2010, 2020, and 2030.

Due to the routing definitions of the TRANSEARCH data, trip ends within Maricopa and Pinal County, which are in ZCTAs outside of the MAG model region are included in this database. Since the MAG TRANSEARCH database will be further processed for use in developing regression equations for the internal portion of IE and EI trips, these ZCTAs were excluded from the processing of the data at later stages.

**Table 3.3 TRANSEARCH Segment to MAG External Station Correspondence**

TRANSEARCH First Segment/Last Segment	MAG External Station Name 1	MAG External Station 1 TRANSEARCH Segment Number	MAG External Station Name 2	MAG External Station 2 TRANSEARCH Segment Number
4000070	I8	4010555		
4000081	I8	4010555		
4000110	I10W	4010436		
4000551	Pinal	4000551		
4000623	I10S	4010454		
4000920	I10S	4010454		
4000980	I10S	4010454		
4001050	U60E	4010504		
4001120	U60E	4010504		
4001280	Pinal	4000551		
4001300	U60E	4010504		
4001380	U60E	4010504		
4001480	I10W	4010436		
4001570	I17	4010517		
4001615	I17	4010517		
4001860	U93	4010515		
4002070	I17	4010517		
4002130	I17	4010517		
4002140	U60E	4010504		
4002350	I17	4010517		
4002380	I17	4010517		
4002430	I17	4010517	S87	4010485

TRANSEARCH First Segment/Last Segment	MAG External Station Name 1	MAG External Station 1 TRANSEARCH Segment Number	MAG External Station Name 2	MAG External Station 2 TRANSEARCH Segment Number
4002440	U60E	4010504	S87	4010485
4002490	I17	4010517		
4002600	I10S	4010454		
4002720	U93	4010515		
4003190	Pinal	4000551		
4003200	I17	4010517		
4006140	Maricopa	4006140		
4009480	I10S	4010454		
4010435	I10W	4010436		
4010468	I10S	4010504		
4010505	U60E	4010504		
4010533	I17	4010517		

## 4.0 Base Year Model Development

### 4.1 INTRODUCTION

The recently updated internal truck travel model development effort was for a base year of 2006; and is a three-step freight truck model, which estimates trip generation, distribution, and traffic assignment for all trucks in the MAG modeling area. The three-step freight truck model produces highway freight truck flows by assigning the internal O-D table of freight truck flows to a highway network. This O-D truck table is produced by applying truck trip generation and distribution steps to existing employment and/or other variables of economic activity for analysis zones. The external truck travel model is also structured in a similar way to produce external truck flows in an O-D table, where either Origin or Destination or both are external to the MAG region. The external productions and attractions are estimated using trip generation equations, and allocated to various origins and destinations using trip distribution models at the TAZ level. The external truck trip tables are then combined with internal truck trip tables by truck type to form the total truck trip tables.

### 4.2 DEVELOPMENT OF EXTERNAL TRUCK TRIP GENERATION

Trip generation equations are developed for the daily truck attractions to MAG TAZs for external-internal (EI) trips and for the daily truck productions from MAG TAZs for internal-external (IE) truck trips. The trip generation equations were developed through the estimation of linear regressions of the TRANSEARCH data and the population and NAICS employment on a zip code basis. The equations were developed at the zip code level because that is the common unit of geography for which the commodity, population, and NAICS employment data are available. The relationships established at the zip code level were applied to the TAZ-level data during the MAG freight model implementation and validation stage.

The initial selection of appropriate employment and population variables to generate commodity volumes was guided by the U.S. Department of Commerce's Bureau of Economic Analysis Input-Output Tables. Those tables indicate the commodities made or used by various industries. The tables were sorted by commodity by NAICS code and the principal industries that made the commodity. Employment totals in those industries were always included as the proposed independent variables to be tested for the production equations. The input-output tables were sorted by NAICS code and commodity groups to identify the principal industries that used a specific commodity. Employment in

those industries was assigned as the independent variables to be tested in developing the attraction equations. The input-output tables also indicated whether the commodity was used in general industrial or personal consumption, in which case the total employment or the total population was assigned as one of the proposed independent variables for the attraction equations.

The TRANSEARCH commodity database includes unlinked shipment records. A trip that involves multiple modes will have two records: once from the origin to a transfer point on the first mode, and then from the transfer point to the destination on the second mode. This introduces spurious productions and attractions at the transshipment terminals. These trips were identified and removed as outliers from the regression and the identification of the amount of special generator traffic in those outliers is discussed in the next section.

The MAG model estimates the daily internal portion of IE/EI trucks produced and attracted by each commodity group to each TAZ in the region, with the exception of special generators, based on the regression equations. The explanatory variables tested within the regression models included employment by NAICS code and population, though population was not found significant in any of the models. The truck trips through the external stations were identified from the TRANSEARCH database.

The production equations were fit to observed annual trucks for each of the nine (out of 10) commodity groups, with the exception of Commodity Group 2, Mining, which was determined solely based on special generator zones. In addition, Commodity Groups 4 and 5 were combined due to a limitation in the NAICS codes available for lumber as explanatory variables for the productions, while Commodity Group 5, Lumber, as an attraction variable proved useful. For production regression, the inability to distinguish NAICS 321 Lumber from all other NAICS32X employment invalidated the usefulness of maintaining Commodity Group 5 as a separate commodity group. The production equations developed through a linear regression are shown in Table 4.1.

The equation yields the annual trucks for each TAZ based on the total NAICS employment type for that TAZ. For all but Commodity Group 6, the production equation is a linear function of the one variable listed (in either logarithmic or non-logarithmic form). For Commodity Group 6, the production equation is a multi-linear function of the two variables listed.

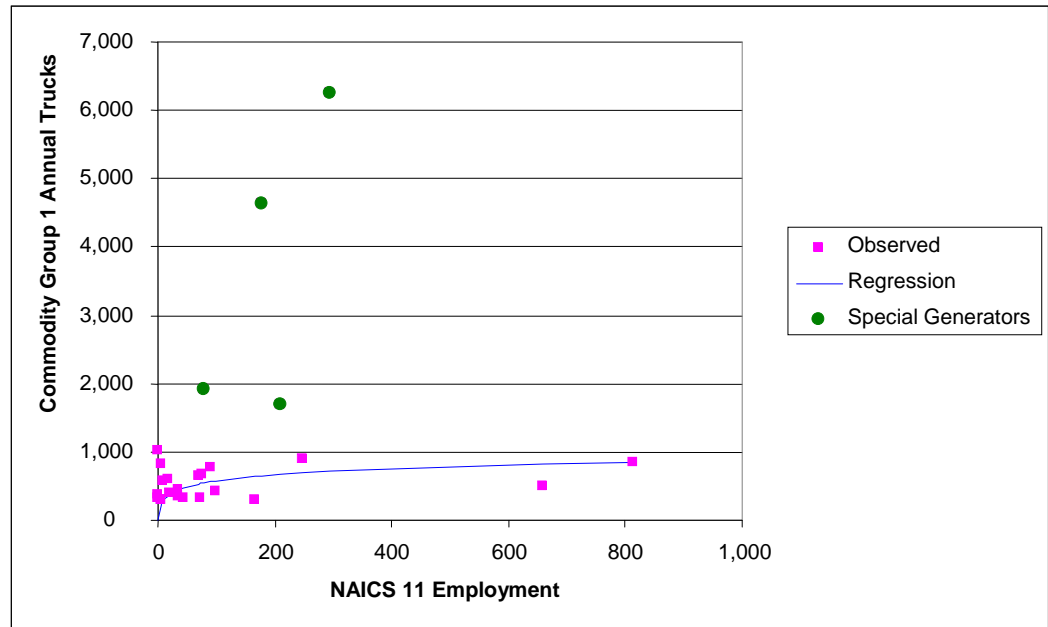
The linear regression equations presented in Table 4.1 are fit to the data without those zip codes which have the special generators. The special generator zip codes were determined by identifying unusually high truck movements, which are outliers to the fit of the truck movements against the explanatory variable(s). Figures 4.1 to 4.8 graphically display the production regression equations fit to the observed data and the magnitude of the special generator values. The y-axis in these figures shows annual trucks, which were used to develop the daily rates shown in Table 4.1.

**Table 4.1      Production Equations**

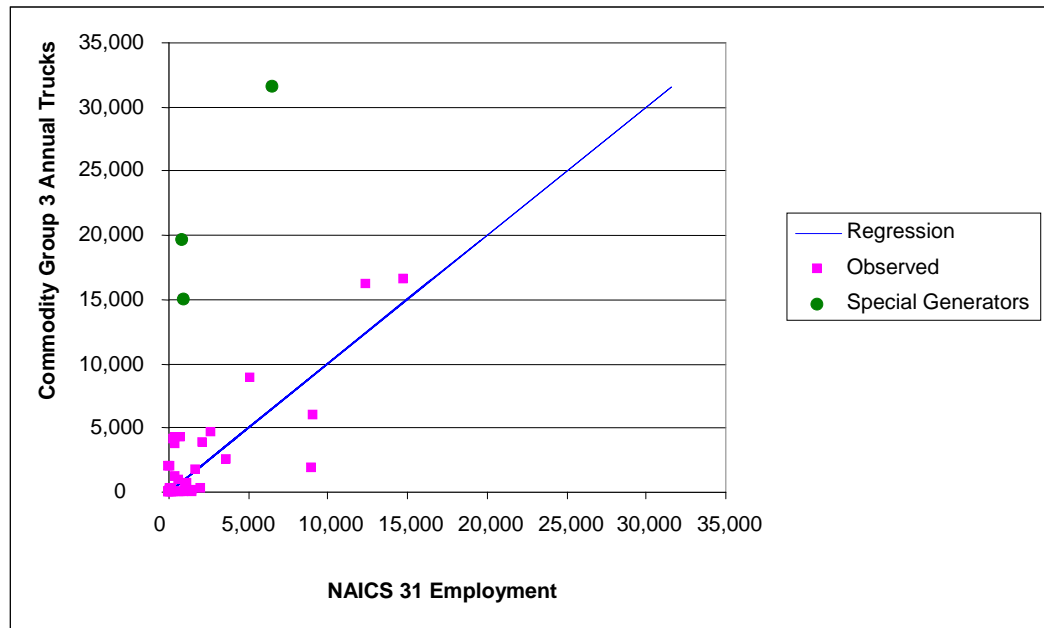
CG #	Name	Variable	Coefficient	t-stats <sup>^</sup>	r <sup>2</sup>
1	Farm	Natural Log of NAICS 11	125.197	9.226	0.810
2	Mining	*	*	*	*
3	All Consumer Manufacturing	NAICS 31	8.281	11.931	0.785
4&5	(Non-consumer) Non-durable Manufacturing Including Lumber	NAICS 32	12.989	10.356	0.691
6	(Non-consumer) Durable Manufacturing	NAICS 32	2.715	7.154	0.795
		NAICS 33	0.451	4.555	
7	Printing	NAICS 32	0.434	12.973	0.816
8	Miscellaneous Freight	Natural log of NAICS 49	0.036	8.073	0.739
9	Empty trucks	Sum of total truck attraction	0.287	68.083	0.994
10	Warehousing	NAICS 42	0.532	8.719	0.613

\*All IE truck productions are from 4 Zip Codes in Pinal County and are processed as special generators.

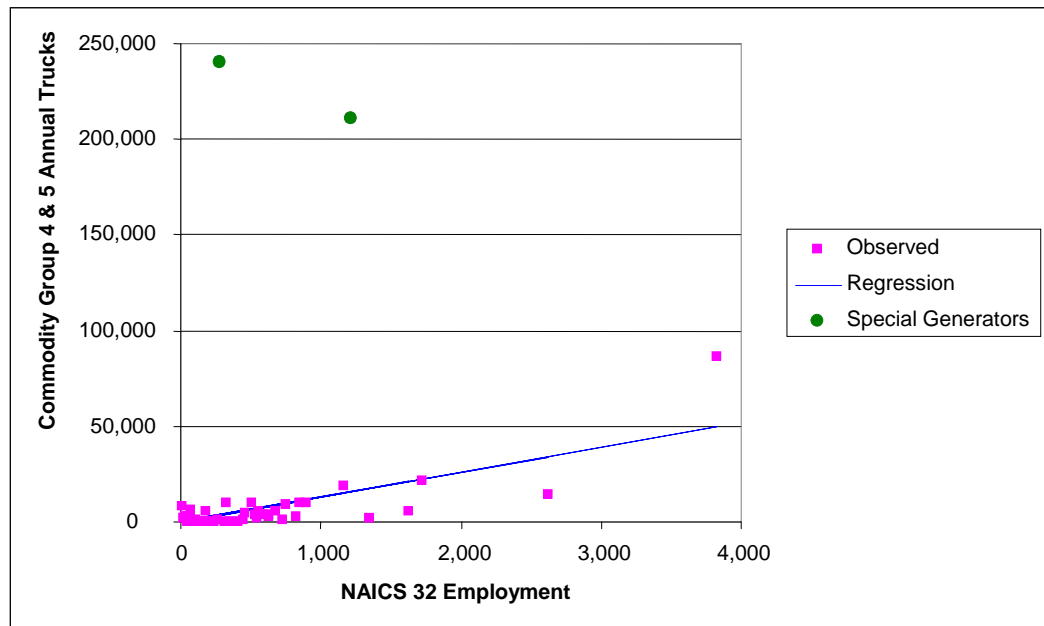
<sup>^</sup> t-stat > 1.96 is statistically significant at 95% confidence level.

**Figure 4.1      Commodity Group 1: Farm Production Regression and Special Generator Values**

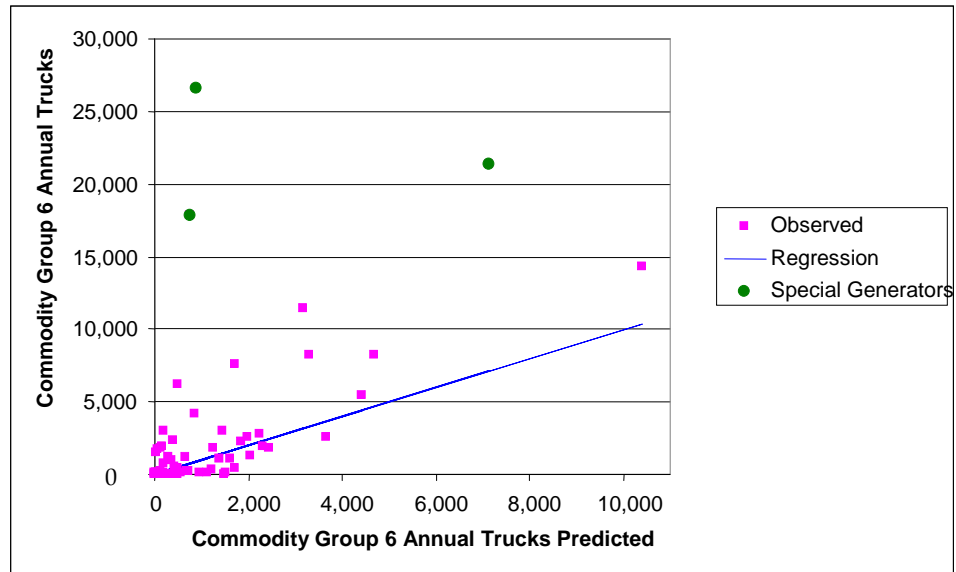
**Figure 4.2 Commodity Group 3: Consumer Manufacturing Production Regression and Special Generator Values**



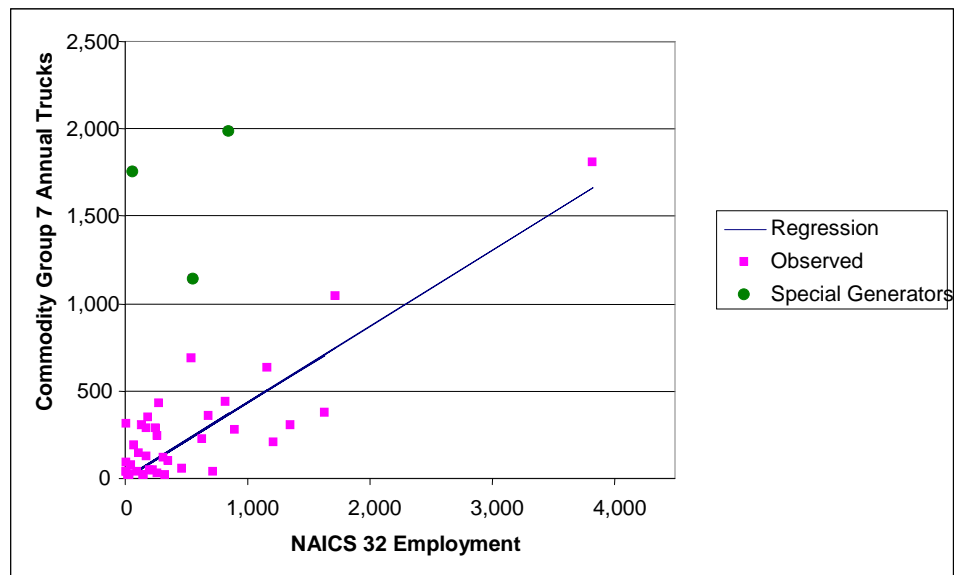
**Figure 4.3 Commodity Groups 4 and 5: Non-durable Manufacturing Production Regression and Special Generator Values**



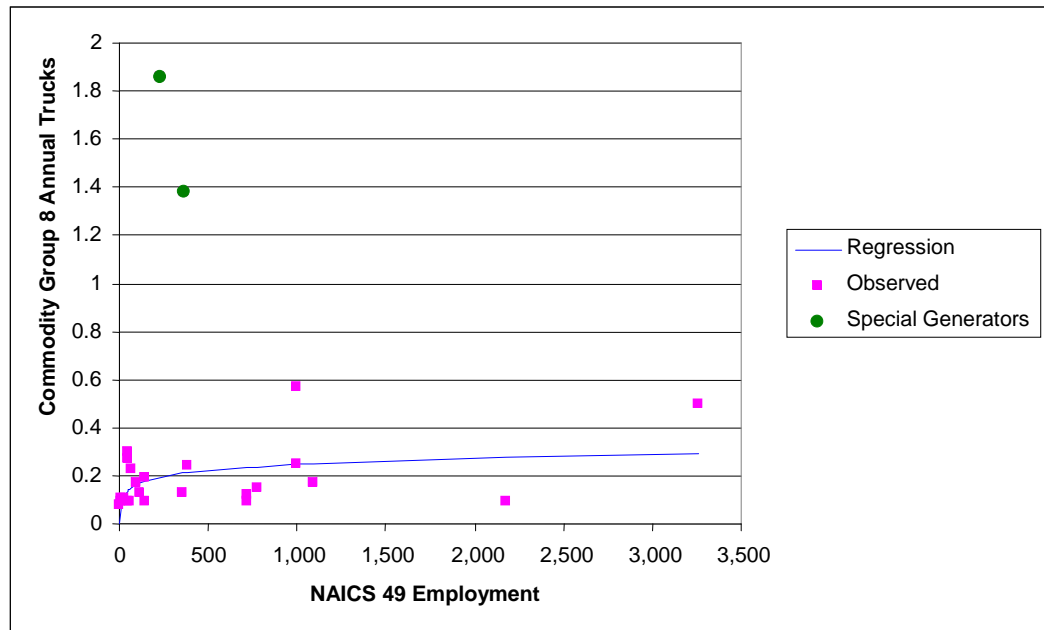
**Figure 4.4** Commodity Group 6: Durable Manufacturing Production Regression and Special Generator Values



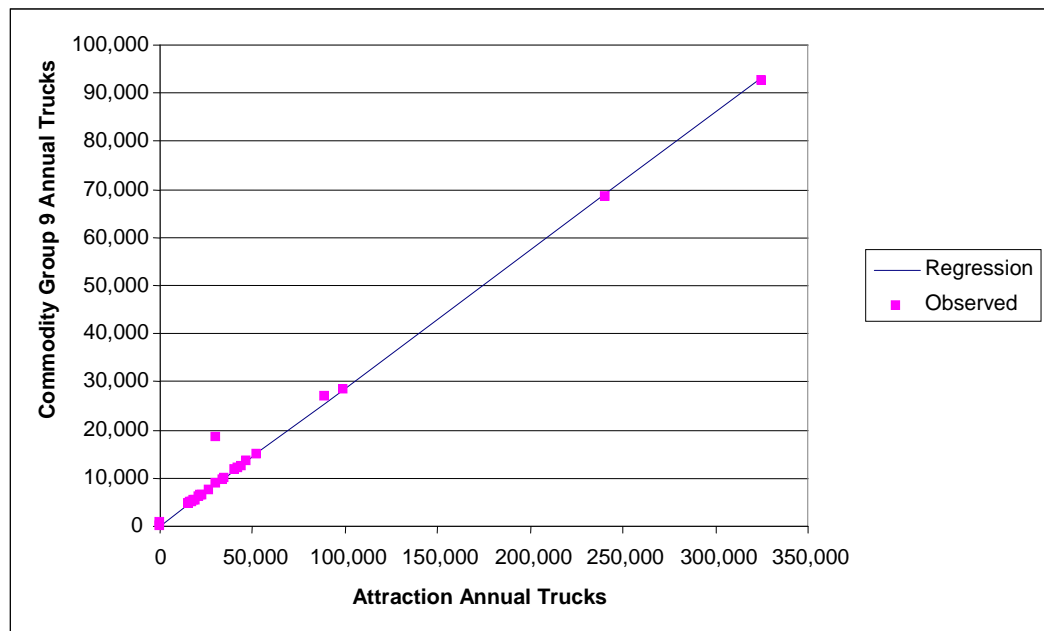
**Figure 4.5** Commodity Group 7: Printing Production Regression and Special Generator Values



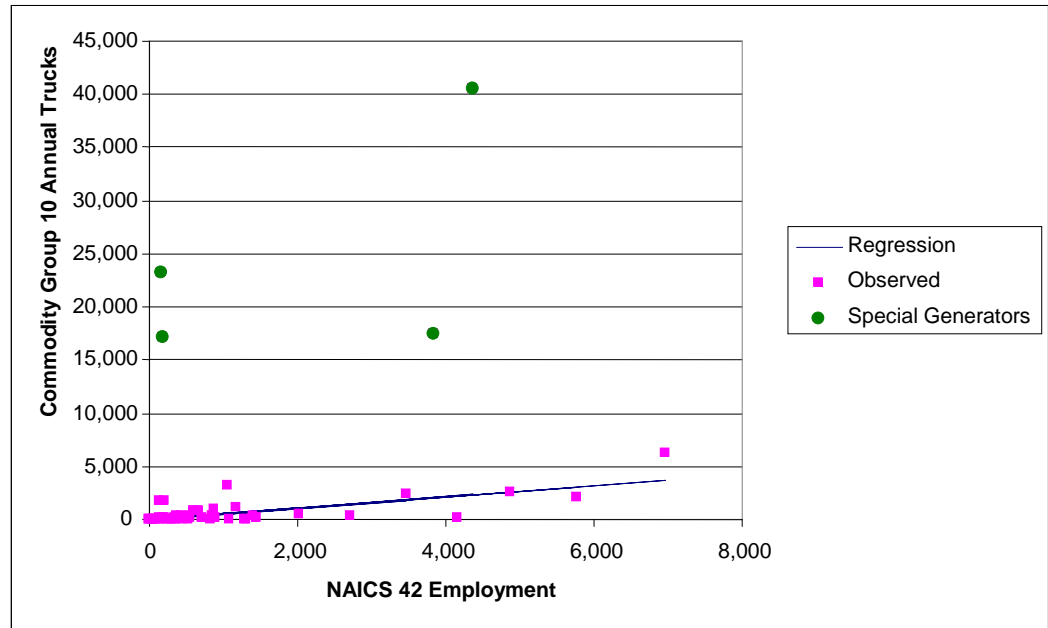
**Figure 4.6 Commodity Group 8: Miscellaneous Freight Production Regression and Special Generator Values**



**Figure 4.7 Commodity Group 9: Empty Trucks Production Regression and Special Generator Values**



**Figure 4.8**    **Commodity Group 10: Warehousing Production Regression and Special Generator Values**



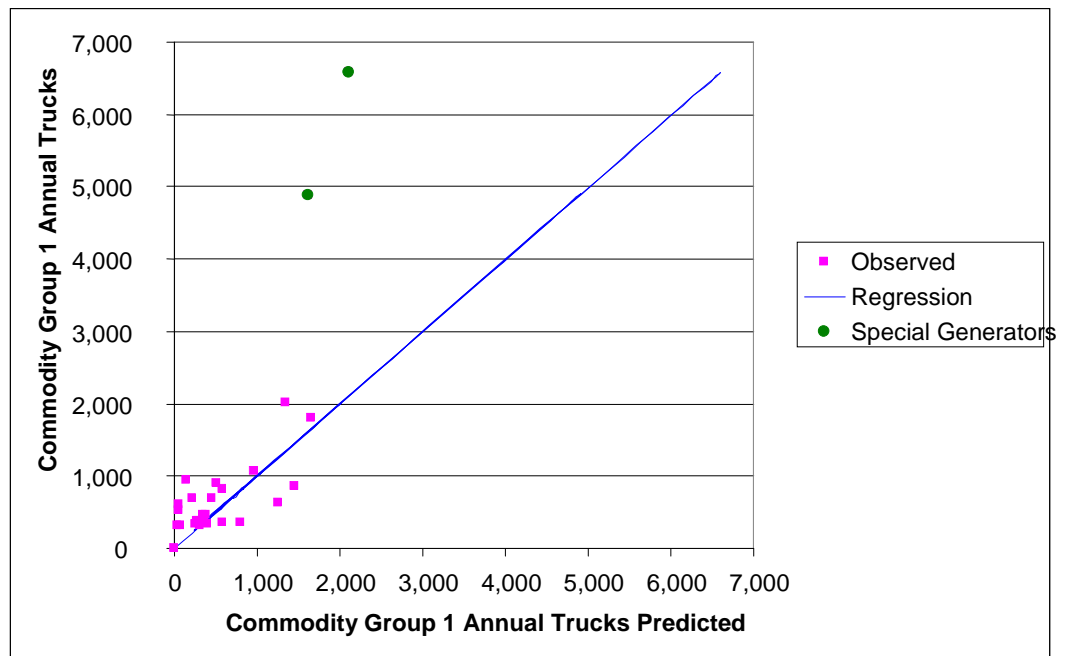
The attraction equations were fit to observed annual trucks for all 10 commodity groups. Commodity Groups 4 and 5 were combined due to a limitation in the NAICS codes available for lumber for attractions. The attraction equations are shown in Table 4.2. The attraction equation is either a linear function of one variable listed or a multi-linear function of the two variables listed.

The linear regression equations presented in Table 4.2 are fit to the data with special generator zip codes removed from the data. Special generator zip codes were determined by identifying unusually high truck movements, which are outliers to the fit of the truck movements against the explanatory variable(s). Figures 4.9 to 4.17 graphically display the attraction regression equations fit to the observed data and the magnitude of the special generator values. The y-axis in these figures shows annual trucks which were used to develop the daily rates shown in Table 4.2.

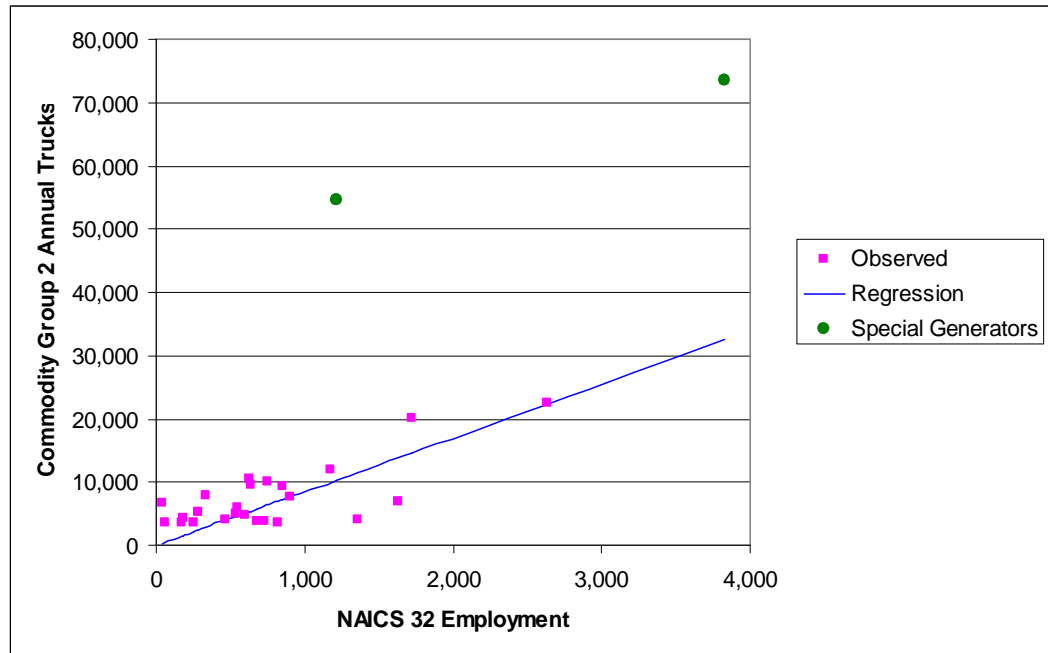
**Table 4.2 Attraction Regression Models**

CG #	Name	Variable	Coefficient	t-stats <sup>^</sup>	r2
1	Farm	NAICS 31	0.266	1.616	0.783
		NAICS 42	0.272	6.599	
2	Mining	NAICS 32	8.492	10.619	0.831
3	All Consumer Manufacturing	NAICS 31	1.626	1.613	0.782
		NAICS 42	1.659	6.591	
4&5	(Non-consumer) Non-durable Manufacturing incl. Lumber	NAICS 42	3.662	8.461	0.757
6	(Non-consumer) Durable Manufacturing	NAICS 42	3.059	8.448	0.756
7	Printing	NAICS 42	0.130	8.441	0.756
8	Miscellaneous Freight	NAICS 32	0.001	10.618	0.831
9	Empty trucks	Sum of total truck production	0.390	29.111	0.910
10	Warehousing	NAICS 42	2.701	8.866	0.759

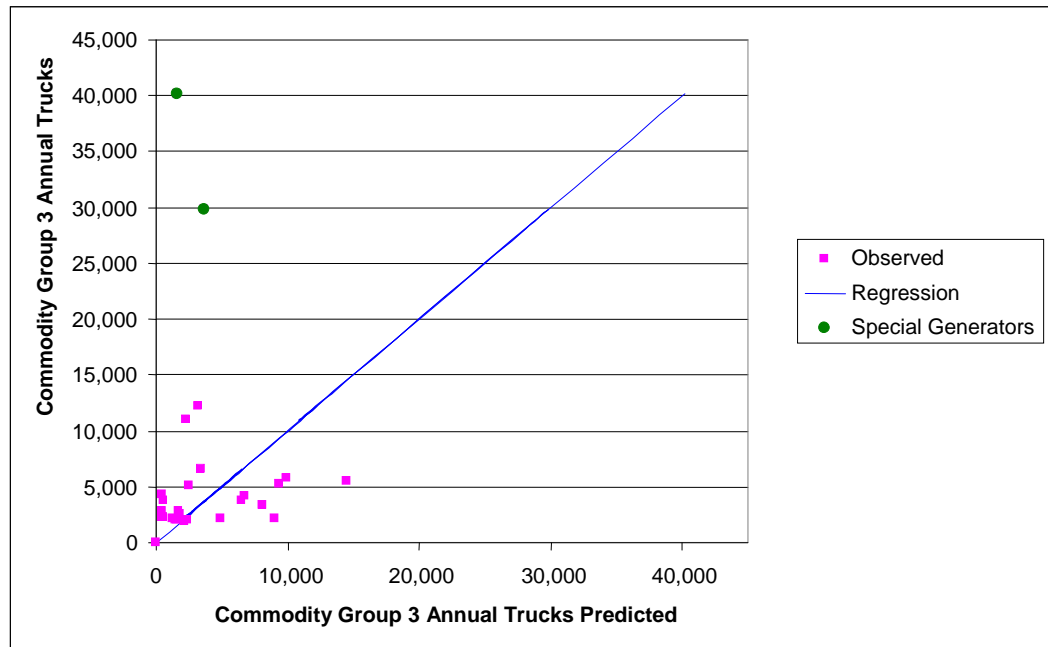
<sup>^</sup> t-stat > 1.96 is statistically significant at 95% confidence level.

**Figure 4.9 Commodity Group 1: Farm Attraction Regression and Special Generator Values**

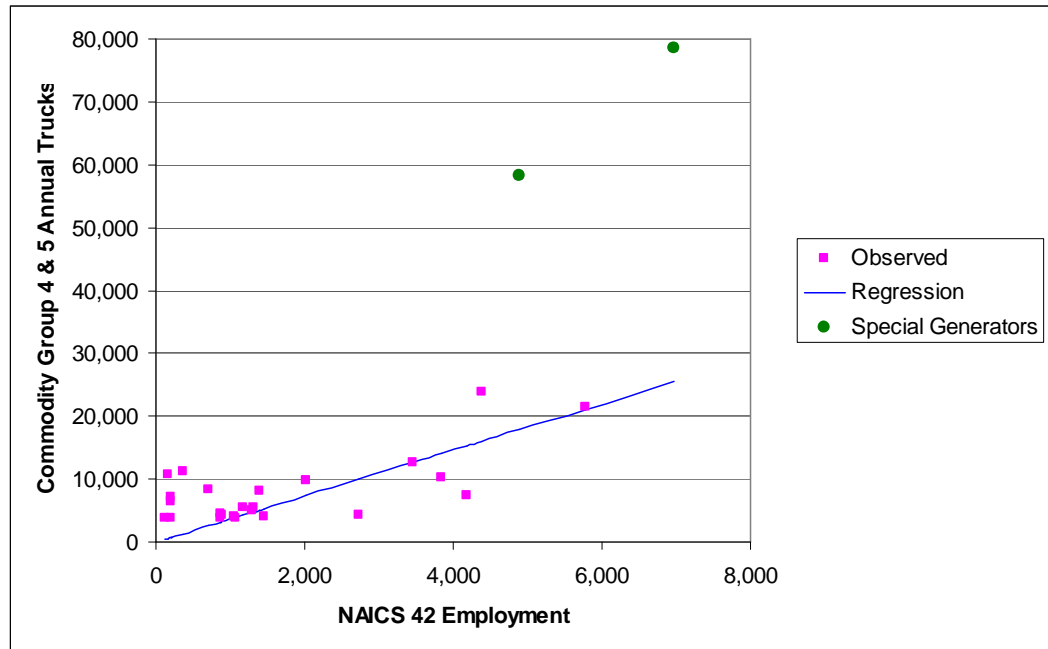
**Figure 4.10 Commodity Group 2: Mining Attraction Regression and Special Generator Values**



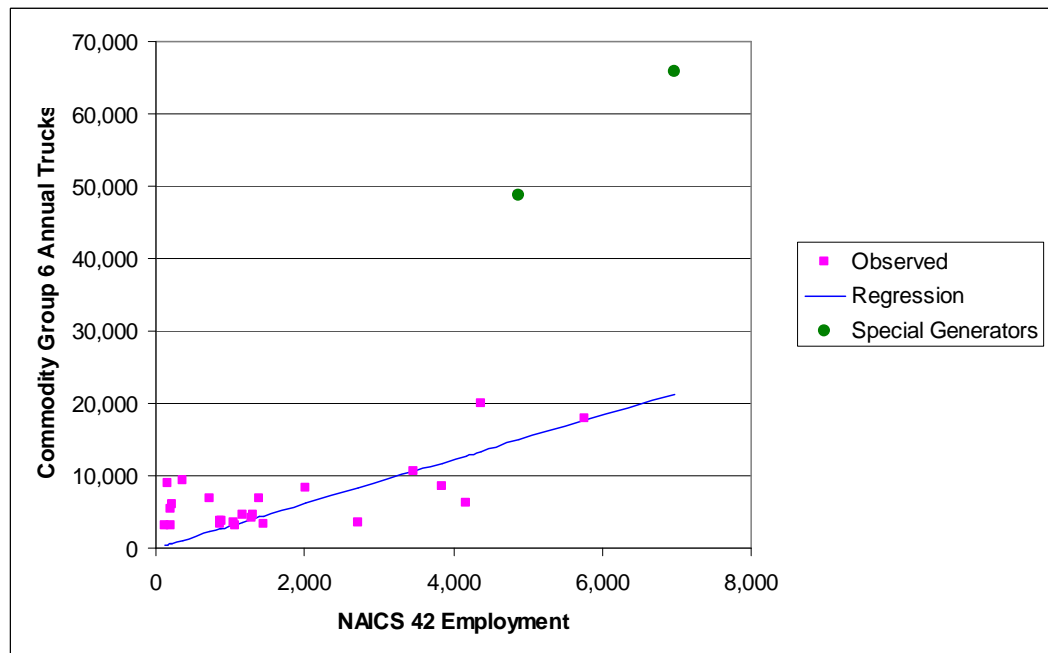
**Figure 4.11 Commodity Group 3: Consumer Manufacturing Attraction Regression and Special Generator Values**



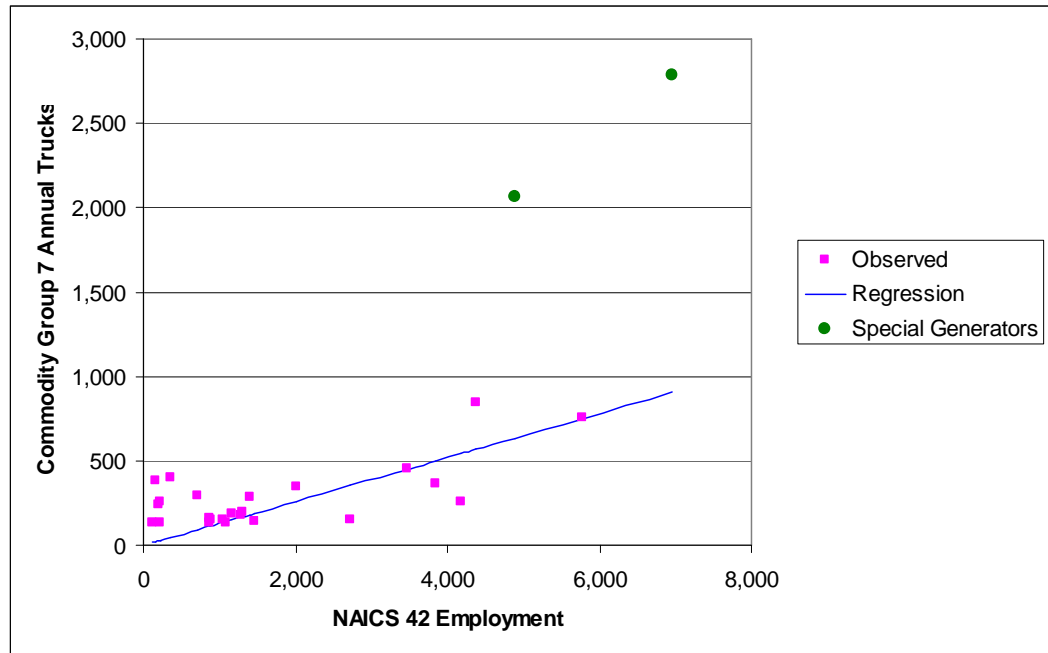
**Figure 4.12 Commodity Group 4: Nondurable Manufacturing Attraction Regression and Special Generator Values**



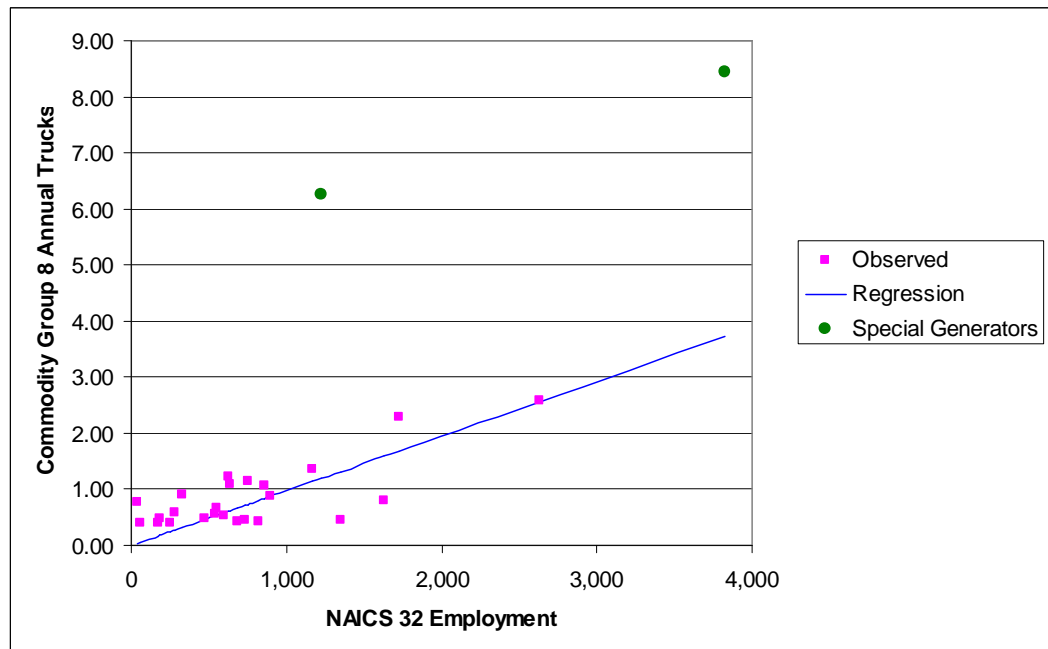
**Figure 4.13 Commodity Group 6: Durable Manufacturing Attraction Regression and Special Generator Values**



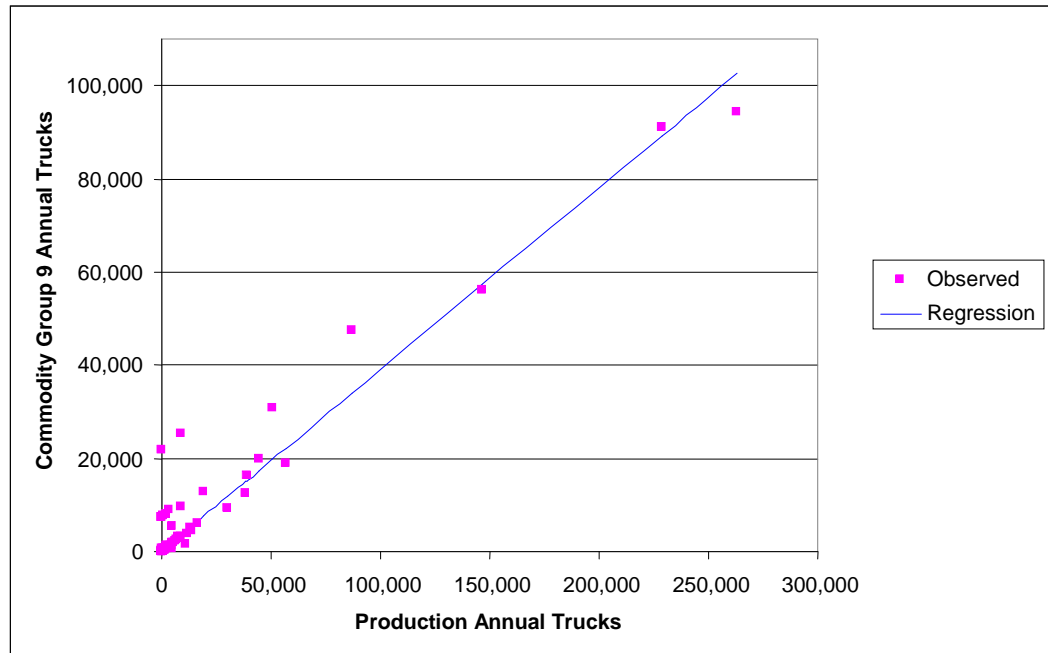
**Figure 4.14 Commodity Group 7: Printing Attraction Regression and Special Generator Values**



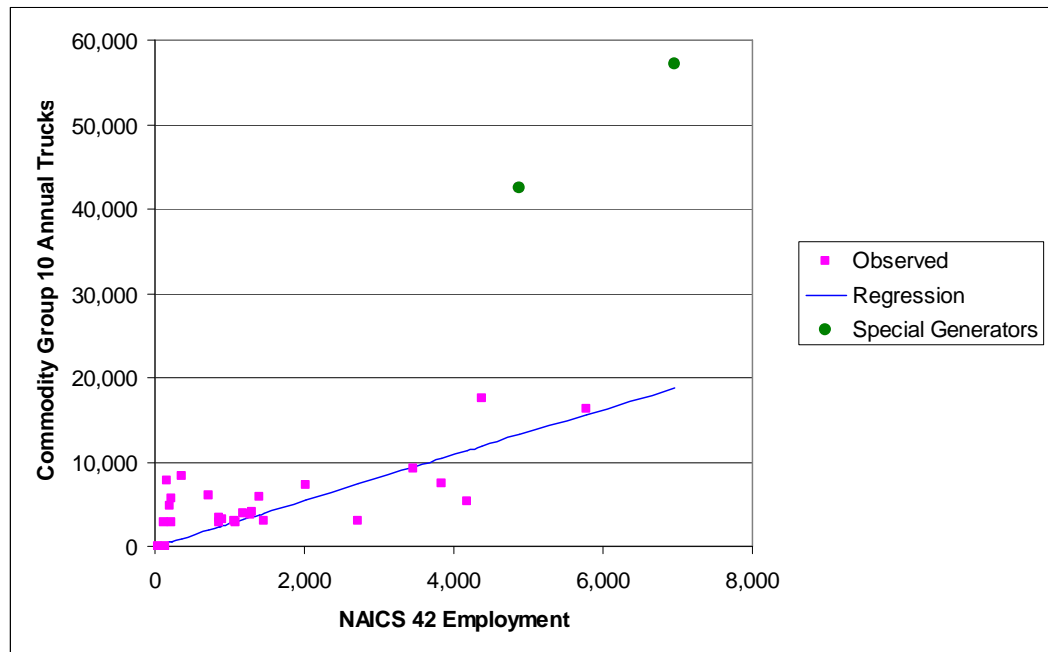
**Figure 4.15 Commodity Group 8: Miscellaneous Freight Attraction Regression and Special Generator Values**



**Figure 4.16 Commodity Group 9: Empty Trucks Attraction Regression and Special Generator Values**



**Figure 4.17 Commodity Group 10: Warehousing Attraction Regression and Special Generator Values**



### 4.3 IDENTIFICATION OF SPECIAL GENERATORS

The special generator values for each commodity group were determined by calculating the difference between the totals from the TRANSEARCH truck data and the predicted annual truck totals. The predicted annual truck values were calculated using the regression equation with the NAICS employment values for the special generator zip code. Tables 4.3 and 4.4 contain the special generator annual truck values produced and attracted to each zip code by commodity group. An examination of the potential special generators in each TAZ was also pursued separately. Using the Bureau of Transportation Statistics GeoFreight database, the point location of freight terminals was identified by the TAZ in which they are located. Using the correspondence table of ZCTAs to TAZ, that information was used to assign the special generator totals by ZCTA in Tables 4.3 and 4.4 to the appropriate TAZ. The special generator values, adjusted from annual to average weekday trucks, were added to each corresponding TAZ for each commodity group after the regression equations are applied.

**Table 4.3 Special Generator Annual Truck Values for Productions**

ZCTA	Production Commodity Group								
	1	2	3	4 & 5	6	7	8	9	10
85003						899			
85008				236,383	17,035				
85009	5,539		25,005				2		
85031						1,723			
85034	1,035								
85040	3,985			194,839			1		
85043	1,359				14,178				38,177
85043									
85210			14,010			1,612			
85225			18,775		25,630				
85226	1,014								
85282									15,441
85326									16,978
85353									23,167

**Table 4.4 Special Generator Annual Truck Values for Attractions**

ZCTA	Attraction Commodity Group								
	1	2	3	4 & 5	6	7	8	9	10
85003									
85008									
85009	4,487	41,009	38,571	53,153	44,444	1,883	5		38,409
85031									
85034									
85040	3,271	44,158	26,113	40,433	33,805	1,433	5		29,235
85043									
85043									
85210									
85225									
85226									
85282									
85326									
85353									

## 4.4 DEVELOPMENT OF EXTERNAL-TO-EXTERNAL TRUCK TRIP TABLE

This section provides a description of the development of the external-to-external (“through”) truck trip table. Also described here is the Frataring process, which is used to develop “through” truck trip tables for any forecast year.

The TRANSEARCH database was first converted into a TransCAD compatible trip table using the ZCTAs as internal zones and the MAG external stations as external cordon points. The flows as annual trucks by commodity were converted to daily trucks and summed over all commodities. These totals were compared to estimates of truck AADTs for each of the external stations using count information available from the FHWA’s Freight Analysis Framework network<sup>1</sup>, as shown in Table 4.5. This shows that while the total numbers of

<sup>1</sup> The FAF is the Freight Analysis Framework, FAF2 Highway Link and Truck Data and Documentation, as prepared for the FHWA. As part of that database, Batelle Memorial Institute, under contract to the FHWA, used the HPMS truck and auto AADTs, supplemented by other information received from state DOTs traffic volume databases,

*Footnote continued*

truck observed over all external stations compares favorably, TRANSEARCH reports truck flows through only 7 of the 11 External stations in the MAG model.

**Table 4.5 TRANSEARCH Daily Truck Trip Ends vs. FAF Daily AADTs**

Station Name	MAG External Station Number	Truck AADT (TRANSEARCH 2005)	Truck AADT (FAF2 2002)
SR 85	1	#N/A	217
I-8	2	2,983	1,606
I-10	3	4,557	9,682
U.S. 60	4	#N/A	823
U.S. 93	5	776	1,826
I-17	6	6,602	4,403
SR 87	7	106	419
SR 88	8	#N/A	823
U.S. 60	9	1,202	983
SR 77	10	#N/A	271
I-10	11	17,077	15,618

The daily truck table derived from TRANSEARCH was adjusted by using a Fratar process within TransCAD. The adjustment targets required by the Fratar process were the truck AADTs for each external station provided by MAG, as shown in Table 4.6. MAG did not collect any count data at the external station on SR 88, as the volumes were expected to be very low, and the roadway is not a through route, but to uninhabitable forest areas. Additionally, SR 88 becomes an unpaved road outside of the MAG modeling area. Therefore, a small daily truck volume, 20 per day, was set as a reasonable target for the Fratar process.

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to populate truck AADTs for each highway link in their network. While the coded volumes can be in error, it has been found to be a credible source of information to use for QA/QC-ing truck volume data received from other sources ([http://ops.fhwa.dot.gov/freight/freight\\_analysis/faf/](http://ops.fhwa.dot.gov/freight/freight_analysis/faf/)).

**Table 4.6 External Station Truck AADTs**

Route	Location	MAG Site Ref	External TransCAD Node ID	FAF2 Truck AADT	MAG External Daily Total
SR 85	At MP 4	9	1	217	107
I-8	At MP 81	10	2	1,606	1,948
I -10	At MP 70	11	3	9,682	10,702
U.S. 60	At MP 72	12	4	823	139
U.S. 93	At MP 177	13	5	1,826	1,088
I-17	At MP 243	1	6	4,403	6,955
SR 87	At MP 199	2	7	419	586
SR 88	#NA	#NA	8	#NA	(est.) 20
U.S. 60	At MP 220	3	9	983	1,150
SR 77	At MP 92	4	10	271	132
I-10	At MP 212	8	11	15,618	12,032

The Fratar process implemented within TransCAD to produce external through truck traffic for any forecast year is carried out in a series of steps as described below.

- For external stations with no reported flows, the row for a nearby related station was copied and pasted into the missing station row to use as the pattern of that external station's initial truck trips, and each cell in this newly pasted row was multiply by 0.001. This step of inserting nonzero flows is necessary because the Fratar process will always produce a zero value if the initial value is zero. The multiplication by 0.001 ensures a nonzero initial value, but will not otherwise bias the flow towards that cell. Since the Fratar process is invariant to uniform scaling, the initial value will not prevent producing the target amount. The columns of missing cells were filled in the same manner. The stations assumed to be related to the missing rows are as follows:

<u>Missing Station</u>	<u>&gt;&gt;&gt;&gt;&gt;</u>	<u>Related Station</u>
SR 85 MAG ID 1	>>>>>	I-8 MAG ID 2
U.S. 60 W MAG ID 4	>>>>>	U.S. 93 MAG ID 5
SR 88 MAG ID 8	>>>>>	SR-87 MAG ID 7
SR 79 MAG ID 10	>>>>>	I-10 S MAG ID 11

- The target daily truck flow for the Fratar process is established from the MAG supplied external station counts as shown in Table 4.6.

- Using TransCAD, the Fratar process was applied using the converted TRANSEARCH O-D table as the table to be adjusted. The origin and destination targets for the ZCTAs remained unchanged.
- For the updated table of total trucks, each new  $T_{ij}$  was divided by the original  $T_{ij}$  to produce a factor. This factor for each  $ij$  pair was applied to each of the appropriate  $ij$  cells in the original multicommodity file. This produces an updated commodity table. The internal trip ends were established through a regression of employment versus TRANSEARCH observations. The Fratared totals from each external station origin to the internal zones were the balanced total of external production used in trip distribution. The Fratared totals from each external station destination from the internal zones were the balanced total of external attractions used in trip distribution. The E-E portion of the updated table (total of all commodities) was saved as that portion of the base O-D table.

The results of the Fratar process was used to establish the external trip ends for the I-E and E-I distribution of truck trips. Additionally, the Fratar process provides the only source of information for the E-E portion of the truck trip table. These Fratared values are shown in Table 4.7, and the E-E portion of the truck trip table is shown in Table 4.8. The differences between E-I and I-E are balanced out during trip distribution and are matched to the average of the two estimates.

**Table 4.7 E-I /I-E Truck Trip Ends – “Fratar”ed Results**

Route	External TransCAD Node ID	External-Internal Productions	Internal-External Attractions
SR 85	1	8	24
I-8	2	117	283
I-10W	3	2,015	1,844
U.S. 60W	4	69	65
U.S. 93	5	461	393
I-17	6	2,833	2,111
SR 87	7	293	276
SR 88	8	10	9
U.S. 60E	9	409	439
SR 77	10	25	22
I-10S	11	2,150	1,905

**Table 4.8 E-E Truck Trip Table – “Fratar”ed Results**

		SR 85	I-8	I-10	U.S. 60	U.S. 93	I-17	SR 87	SR 88	U.S. 60	SR 77	I-10	Total
	MAG ID	1	2	3	4	5	6	7	8	9	10	11	
SR 85	1									0	0		0
I-8	2									2		193	195
I-10	3									30	36	3,148	3,213
U.S. 60	4									0	0		0
U.S. 93	5									2		81	82
I-17	6	24	24	104						7	3	221	383
SR 87	7												0
SR 88	8												0
U.S. 60	9	1	1	21	0	2	2				1	117	145
SR 77	10	0	0	36	0					1			37
I-10	11			3,032		118	118			61			3,329
<b>Total</b>		<b>26</b>	<b>26</b>	<b>3,193</b>	<b>0</b>	<b>119</b>	<b>119</b>	<b>0</b>	<b>0</b>	<b>102</b>	<b>40</b>	<b>3,759</b>	<b>7,385</b>

## 5.0 Base Year Model Validation

The objective of the base year model validation was to calibrate the external truck model and validate the whole truck travel model – internal and external together. This chapter provides a description of the vehicle classification counts used to validate the truck model, and a summary of assignment results that compares the model volumes against the classification counts.

### 5.1 VEHICLE CLASSIFICATION COUNTS

MAG's 2007 external travel surveys were used as the primary source for calibrating the external truck travel model. The 2006 vehicle classification counts, which consist of truck counts by the FHWA classification system on arterials, were also used to validate the whole truck model.

The Freeway Management System (FMS) data was also reviewed, and is maintained by AZDOT, and is for 24 hours. The classification of trucks in the FMS data, however, is length-based, which is different from the FHWA classification system that MAG uses. The two lengths considered in the FMS data are 30 to 55 feet (delivery type trucks) and greater than 55 feet (large trucks). There is, however, no direct correlation of these truck types to that of MAG truck model's truck types.

MAG collected truck classification counts on arterials throughout the region, but not on freeways. Therefore, screenlines for trucks were not available for validation of the truck model. Though truck counts on freeways and expressways were available from AZDOT, they were not classified in a manner that MAG model stratifies truck types. While the development of truck count screenlines to support validation of the truck model is preferred, given the limitations of the data, it was decided to validate only to the sum of medium and heavy trucks on arterials only. Also, internal and external trucks were included together and were validated to counts grouped by city in which the counts were located that served as a substitute to screenlines. It was, however, recognized that this is not ideal, since an error repeated on one route through a city would be added for all of the counts along that route. Therefore, the development of validation truck count screenlines was considered to be a next step in truck model validation once the data becomes available. The final validation results of the modeled daily truck volumes compared against observed counts is discussed in the following section.

### 5.2 TRIP ASSIGNMENT RESULTS

The internal and external truck trip tables were assigned with the passenger car trip tables to implement a multiclass equilibrium assignment of all vehicles to the

highway network. The external truck trip volumes were controlled to the external stations AADTs, so multiple assignments do not alter the external truck volumes. The new assignment from the 2007 base year model yielded new travel time skims, which were fed back into the truck trip distribution process. As a result, the internal truck trip flows were affected and were calibrated again. This was done based on the observed data gathered previously from O/D-based truck trip diaries by truck type. The internal truck trip rates were adjusted by comparing the modeled truck volumes to the observed classification counts. This was an iterative process until the total truck volumes were validated against observed data.

### **Multiclass Assignments**

Trip assignment of the truck trips was completed using an equilibrium highway assignment. Truck trips were assigned simultaneously with the passenger model, because congestion has a significant impact on travel times experienced by trucks. Truck trips are assigned separately by type using the multiclass assignment technique for five vehicle types:

1. Single-occupant passenger vehicles,
2. High-occupant passenger vehicles,
3. Light trucks,
4. Medium trucks, and
5. Heavy trucks.

### **Passenger Car Equivalents**

The original truck model was developed using a conversion of truck volumes to passenger car equivalents (PCE) for assignment purposes. This factor provides a means to account for the fact that larger trucks take up more capacity on the roads than passenger cars. However, this process was subsequently changed and the existing model does not use any PCEs; that is, vehicles, and not PCEs, are assigned to the highway network. The use of PCEs is a fundamental change in the model that has larger implications on link capacity, and on the validation and route choice of autos and external trucks, as well as the internal trucks that were the focus of this study. If PCEs are to be included in the MAG model, and there are advantages to making this change, it should be undertaken in conjunction with the next model update.

### **Validation**

As part of the 2006 Arterial Count Study, MAG collected vehicle classification counts on about 200 locations. The classification was based on the FHWA classification scheme, and the counts for Classes 5 to 7 were grouped together for medium trucks, and Classes 8 to 13 for heavy trucks. Since the new base year is 2007, growth factors were applied to these counts to obtain 2007 counts. As the

trip assignment model produces truck volumes in vehicles, these are directly compared against the counts on the arterials. Table 5.1 provides the results from the truck assignments of the new truck model compared against the counts at the city level in the MAG region. As there are no screenlines available, it was decided to use cities as a proxy to screenlines for validation purposes.

Table 5.1 indicates that there are three cities, namely, Buckeye, Carefree and Fountain Hills, which have differences between volumes and counts, when medium and heavy trucks are combined, by over 40 percent. This is acceptable due to the low-volume facilities passing through these Cities that carry less than 1,000 medium and heavy trucks combined per day. All other cities are within the validation targets derived from the most recent guidelines from the FHWA<sup>2</sup>. However, there are two exceptions – Glendale and Surprise, where the new truck model underestimates total medium and heavy trucks by about -39 percent and -31 percent, respectively. Both these Cities, which fall under the volume group of 10,000 to 15,000, should be within a target of +/-25 percent according to the FHWA guidance. With the lack of any freeway counts, it is hard to tweak the model any more to validate model volumes in these two cities to counts. This should be further improved when screenlines are developed and new freeway counts are collected. The total number of medium and heavy trucks on all the arterial count locations is within seven percent of the observed values.

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<sup>2</sup> U.S. Department of Transportation, Travel Model Improvement Program, *Model Validation and Reasonableness Checking Manual*, prepared by Barton Aschman Associates and Cambridge Systematics, Inc., for the Federal Highway Administration, February 1997, page 107.

**Table 5.1 Comparison of Truck Volumes and Counts on Arterials**

City	2007 Arterial Counts			2007 New Truck Model Volumes			Difference		
	Medium	Heavy	Medium & Heavy	Medium	Heavy	Medium & Heavy	Medium	Heavy	Medium & Heavy
Avondale	3,758	2,325	6,083	2,133	5,774	7,907	-43%	148%	30%
Buckeye	564	640	1,204	630	1,428	2,058	12%	123%	71%
Carefree	1,244	349	1,593	244	667	911	-80%	91%	-43%
Chandler	5,785	11,394	17,179	4,916	12,911	17,827	-15%	13%	4%
Fountain Hills	686	1,970	2,656	1,417	3,838	5,255	107%	95%	98%
Gilbert	4,639	3,766	8,405	1,916	5,134	7,049	-59%	36%	-16%
Glendale	18,290	14,229	32,519	5,463	14,475	19,938	-70%	2%	-39%
Mesa	8,096	19,211	27,307	5,713	16,211	21,925	-29%	-16%	-20%
Paradise Valley	1,445	2,293	3,738	1,007	2,790	3,797	-30%	22%	2%
Peoria	3,535	3,115	6,650	2,065	4,315	6,380	-42%	39%	-4%
Phoenix	76,129	143,961	220,090	80,054	192,551	272,605	5%	34%	24%
Queen Creek	1,259	444	1,703	287	753	1,040	-77%	70%	-39%
Scottsdale	10,016	27,503	37,519	10,113	24,478	34,591	1%	-11%	-8%
Surprise	14,189	6,076	20,265	5,116	8,962	14,077	-64%	47%	-31%
Tempe	5,693	16,332	22,025	7,394	16,245	23,639	30%	-1%	7%
Tonopah	56	40	96	24	67	91	-57%	67%	-5%
<b>Total</b>	<b>155,384</b>	<b>253,648</b>	<b>409,032</b>	<b>128,491</b>	<b>310,598</b>	<b>439,088</b>	<b>-17%</b>	<b>22%</b>	<b>7%</b>

## 6.0 Forecast Year Model Development

### 6.1 INPUT DATA

The forecast year data that MAG has was first reviewed to identify data gaps such as socio-economic data for future years, and then prepare new data required to bridge the gaps. The data required to develop truck travel model forecasts are – employment and population, TRANSEARCH commodity flows, and MAG’s travel forecasting (passenger) model.

#### Employment Data

This includes the employment data at 2-digit NAICS level that is a key input for the truck travel model. Cambridge Systematics recommended a procedure for MAG to develop forecast year employment data at the 2-digit NAICS level, which was used to develop data for all required forecast years.

The internal and external truck models use different set of NAICS-2 employment variables as the internal and external truck trips are influenced by different industries, nature of customers of these industries, and their locations. Table 6.1 shows a comparison of growth rates among total employment, employment that impacts long-haul external commodity flows, and population in the region between 2007 and 2031.

**Table 6.1      Employment and Population Growth Rates**

<b>MAG Modeling Area Total Employment</b>	
Year 2007	2,019,842
Year 2031	3,635,668
Compound Annual Growth Rate	2.48
<b>MAG Modeling Area Commodity Flow Employment</b>	
Year 2007	318,849
Year 2031	514,730
Compound Annual Growth Rate	2.02
<b>MAG Modeling Area Population</b>	
Year 2007	4,539,777
Year 2031	7,685,335
Compound Annual Growth Rate	2.22

The rate of change of total employment is higher than the population indicating that the region is going to see an increase in people joining the workforce. On the other hand, the employment impacting commodity flows is growing at a lower rate than population which indicates that productivity in these industries is going to increase in the future.

#### TRANSEARCH Data

The TRANSEARCH database for forecast years is a key input to develop growth factors for all interim forecast years. These growth factors are necessary for certain components of the external truck model such as special generators that are not captured by the model.

The base year of the TRANSEARCH data is 2005 and the forecast years are 2010, 2020 and 2030. In order to compute growth rates, the 2005 and 2030 annual tonnage was used to develop growth factors by commodity group. These growth factors are nothing but annual percentage rates (APR) that is used to compute external station targets for the forecast year internal-external productions and external-internal attractions. Tables 6.2 and 6.3 show these APRs by commodity group that were applied to each interim forecast year. Table 6.4 presents the APRs for each MAG external station as derived from the TRANSEARCH database.

**Table 6.2 Internal-External Annual Percentage Rates**

Commodity Group	2005 Annual Trucks from TRANSEARCH	2030 Annual Trucks from TRANSEARCH	Growth Factor (2005 to 2030)	Annual Percentage Rate
Farm	40,720	49,574	122%	0.8%
Mining	118,356	120,811	102%	0.1%
All Consumer Manufacturing	176,408	218,796	124%	0.9%
(Non-consumer) Nondurable Manufacturing Including Lumber	267,943	308,311	115%	0.6%
(Non-consumer) Durable Manufacturing	728,863	709,624	97%	-0.1%
Printing	15,423	19,298	125%	0.9%
Miscellaneous Freight	15	25	163%	2.0%
Empty trucks	811,998	1,387,932	171%	2.2%
Warehousing	151,960	435,611	287%	4.3%
<b>Total</b>	<b>2,311,687</b>	<b>3,249,980</b>	<b>141%</b>	<b>1.4%</b>

**Table 6.3 External-Internal Annual Percentage Rates**

Commodity Group	2005 Annual Trucks from TRANSEARCH	2030 Annual Trucks from TRANSEARCH	Growth Factor (2005 to 2030)	Annual Percentag e Rate
Farm	46,646	83,553	179%	2.4%
Mining	465,977	318,740	68%	-1.5%
All Consumer Manufacturing	257,665	471,837	183%	2.4%
(Non-consumer) Nondurable Manufacturing Including Lumber	330,477	484,444	147%	1.5%
(Non-consumer) Durable Manufacturing	744,111	1,460,907	196%	2.7%
Printing	17,923	36,725	205%	2.9%
Miscellaneous Freight	68	54	79%	-0.9%
Empty trucks	813,229	1,250,739	154%	1.7%
Warehousing	440,289	1,195,209	271%	4.1%
<b>Total</b>	<b>3,116,385</b>	<b>5,302,206</b>	<b>170%</b>	<b>2.1%</b>

**Table 6.4 External-External Annual Percentage Rates**

MAG Origin Highway	MAG Origin (external station / TAZ)	MAG Destinatio n Highway	MAG Destination (external station / TAZ)	2005 Annual Trucks from TRANSEARCH	2030 Annual Trucks from TRANSEARCH	Growth Factor (2005 to 2030)	Annual Percentage Rate
I8	2	I17	6	190,888	486,621	255%	3.8%
I8	2	U60E	9	2,183	4,617	212%	3.0%
I8	2	I10S	11	174,165	546,284	314%	4.7%
I10W	3	I17	6	17,164	30,340	177%	2.3%
I10W	3	U60E	9	15,755	28,920	184%	2.5%
I10W	3	I10S	11	1,374,810	3,419,948	249%	3.7%
U93	5	U60E	9	457	612	134%	1.2%
U93	5	I10S	11	18,022	36,009	200%	2.8%
I17	6	I8	2	132,936	164,790	124%	0.9%
I17	6	I10W	3	36,338	27,663	76%	-1.1%
I17	6	U60E	9	2,718	3,241	119%	0.7%
I17	6	I10S	11	74,147	118,336	160%	1.9%
U60E	9	I8	2	17,309	35,919	208%	3.0%
U60E	9	I10W	3	18,142	61,967	342%	5.0%
U60E	9	U93	5	871	2,517	289%	4.3%

U60E	9	I17	6	2,374	5,259	222%	3.2%
U60E	9	I10S	11	97,151	210,535	217%	3.1%
I10S	11	I8	2	257,552	330,407	128%	1.0%
I10S	11	I10W	3	1,760,225	2,194,040	125%	0.9%
I10S	11	U93	5	43,787	76,166	174%	2.2%
I10S	11	I17	6	57,510	92,703	161%	1.9%
I10S	11	U60E	9	41,794	62,168	149%	1.6%
				<b>4,336,300</b>	<b>7,939,063</b>	<b>183%</b>	<b>2.4%</b>

### MAG Travel Forecasting Model

This is essential to run forecast year truck model along with the passenger model trip tables. The integrated travel forecasting model that consists of passenger model, internal truck model and external truck model was used to generate all the truck forecast volumes and VMT for various horizon years. The corresponding input data such as employment and population, growth factors, and special generators were input into each model run.

## 6.2 TRUCK FORECASTS

The development of the new truck model, both internal and external, was a success. The resources were spent effectively on data collection as part of the internal truck model update, and development of the internal truck model. Localized commodity flow data was used to update the external truck model, and both the internal and external models were integrated with MAG's travel demand model, and the whole truck model was validated to observed data.

Cambridge Systematics assisted MAG staff in producing forecasts – truck volumes and truck VMT – for several forecast years, as shown in Table 6.5. The overall increase in total trucks is 3.4 percent per year or 77 percent from 2008 to 2031. The heavy trucks are growing at a slower rate than light and medium trucks across different forecast years.

**Table 6.5 Truck Volumes by Truck Type for Forecast Years**

Model Year	Light Trucks (Class 3)	Medium Trucks (Classes 5-7)	Heavy Trucks (Classes 8-13)	Total Trucks	Percent Increase
2008	55,947,450	13,306,266	16,619,186	85,872,902	-
2010	59,047,360	19,099,125	20,064,240	98,210,725	14%
2015	78,383,186	23,946,270	22,606,842	124,936,297	27%
2018	75,437,968	31,633,683	22,907,442	129,979,093	4%
2028	97,447,590	25,363,584	24,746,358	147,557,532	14%
2030	99,784,126	25,448,751	24,690,680	149,923,557	2%
2031	101,026,015	25,916,324	25,437,571	152,379,910	2%
2008 to 2031	81%	95%	53%	77%	
Increase per Year	3.5%	4.1%	2.3%	3.4%	

**Table 6.6 Total VMT versus Truck VMT for Forecast Years**

Year	Total VMT	Percent Increase in Total VMT	Truck VMT	Percent Increase in Truck VMT
2008	104,839,528	-	34,281,226	-
2010	113,360,656	8%	38,663,832	13%
2015	134,151,969	18%	45,783,049	18%
2018	143,152,955	7%	48,117,465	5%
2028	181,378,848	27%	59,081,797	23%
2030	187,761,604	4%	60,591,545	3%
2031	187,797,641	0%	61,650,447	2%
2008 to 2031	79%	-	80%	-
Increase per Year	3.4%	-	3.5%	-



## 7.0 Conclusions and Recommendations

### 7.1 CONCLUSIONS

The development of the new truck model, both internal and external, was a success. The resources were spent effectively on data collection as part of the internal truck model update, and development of the internal truck model. Localized commodity flow data was used to update the external truck model, and both the internal and external models were integrated with MAG's travel demand model, and the whole truck model was validated to observed data.

There are several unique and innovative features employed in this truck model update. These are:

- Collected O-D travel information from trucks that travel within the MAG region using different surveying techniques for different sectors;
- Innovative way of distributing trucks based on land use-to-land use interchanges rather than the traditional O-D based gravity model;
- Developed linear and log-linear relationships between external freight flows and underlying socioeconomic activity at the zonal level;
- Integrated land use-based internal truck model and commodity flow-based external truck model into a "hybrid" truck model.

The base year model was validated to arterial counts and Cities served as a proxy to screenlines. The external station counts were used to control the external truck volumes coming, going out and flowing through the MAG region. Though length-based freeway counts were available, they were not used to validate axle-based truck volumes as there was no direct correlation among the two.

### 7.2 RECOMMENDATIONS

Some of the observations made were high truck vehicle-miles traveled (VMT) on freeways. However, since there was no data to validate truck volumes on freeways, it was not possible to adjust the model any further. The only source of counts on major highways was the external station AADTs that control the entry and exit of truck trips. So once new freeway classification counts are obtained, and screenlines created, the truck model should be calibrated again to achieve better valid results. The total truck VMT should also be compared against HPMS VMT at an aggregate level.